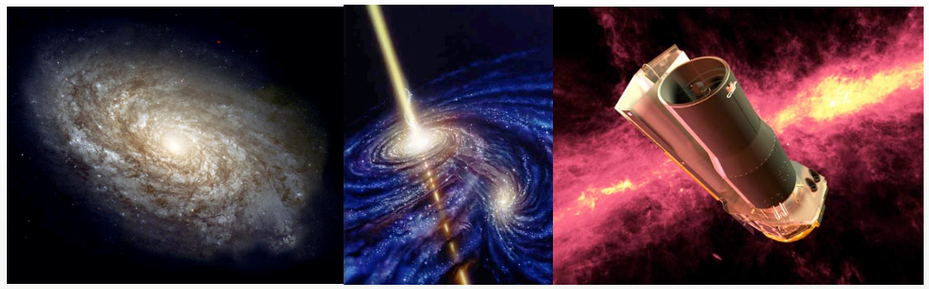
Durham University

Growth of Black Holes
2010, Durham, UK

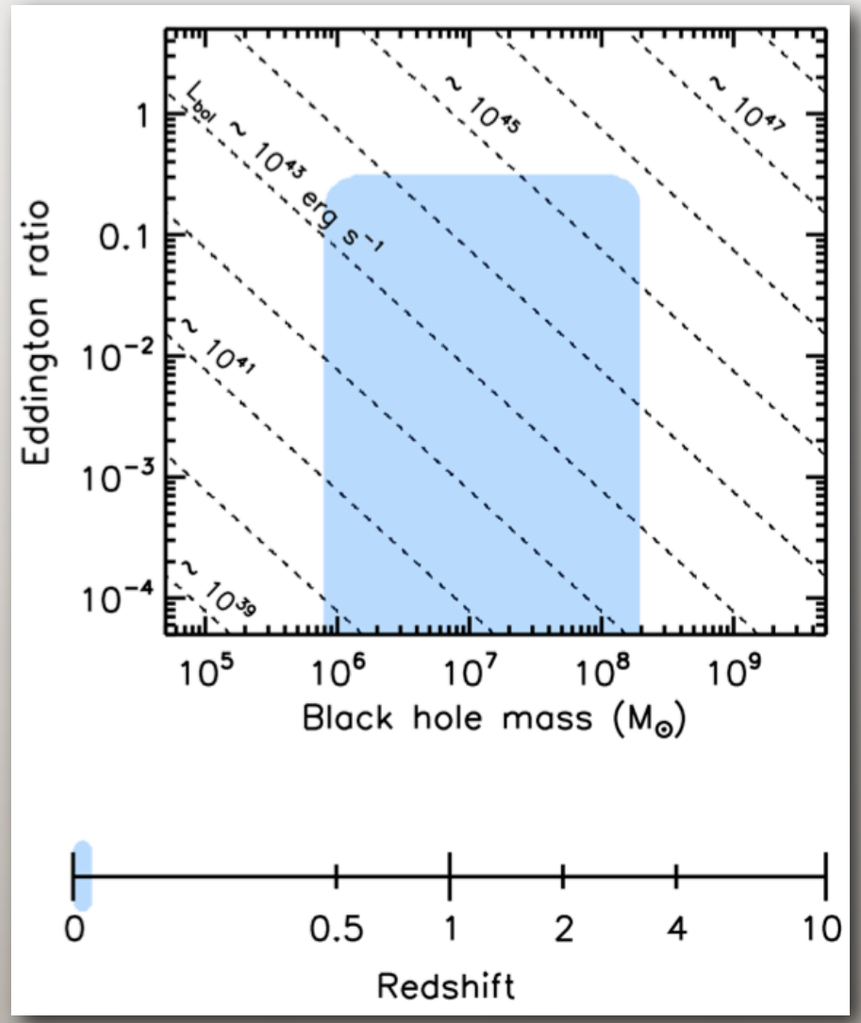


The Incidence & Present-Day Growth of SMBHs

A. D. Goulding (Durham)
D.M. Alexander (Durham), J.R. Mullaney (Durham)
B.D. Lehmer (Johns Hopkins)

2010, MNRAS, 406, 597
arXiv:1003.3015

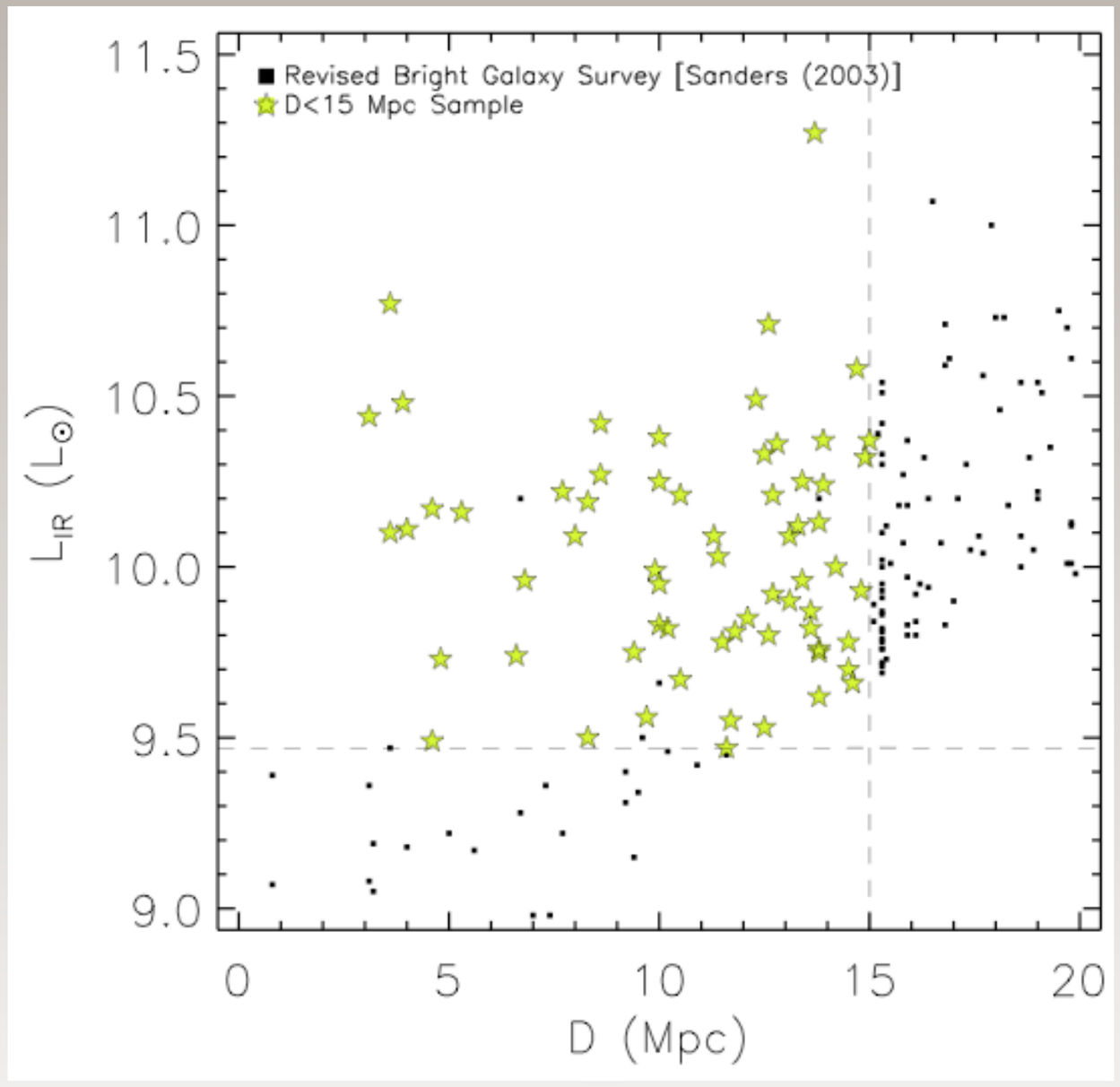
andrew.goulding@durham.ac.uk

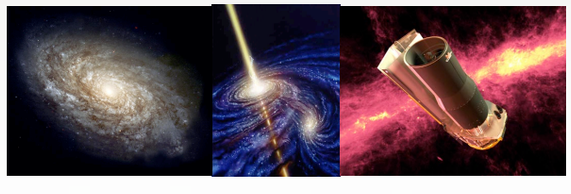


Science & Technology Facilities Council

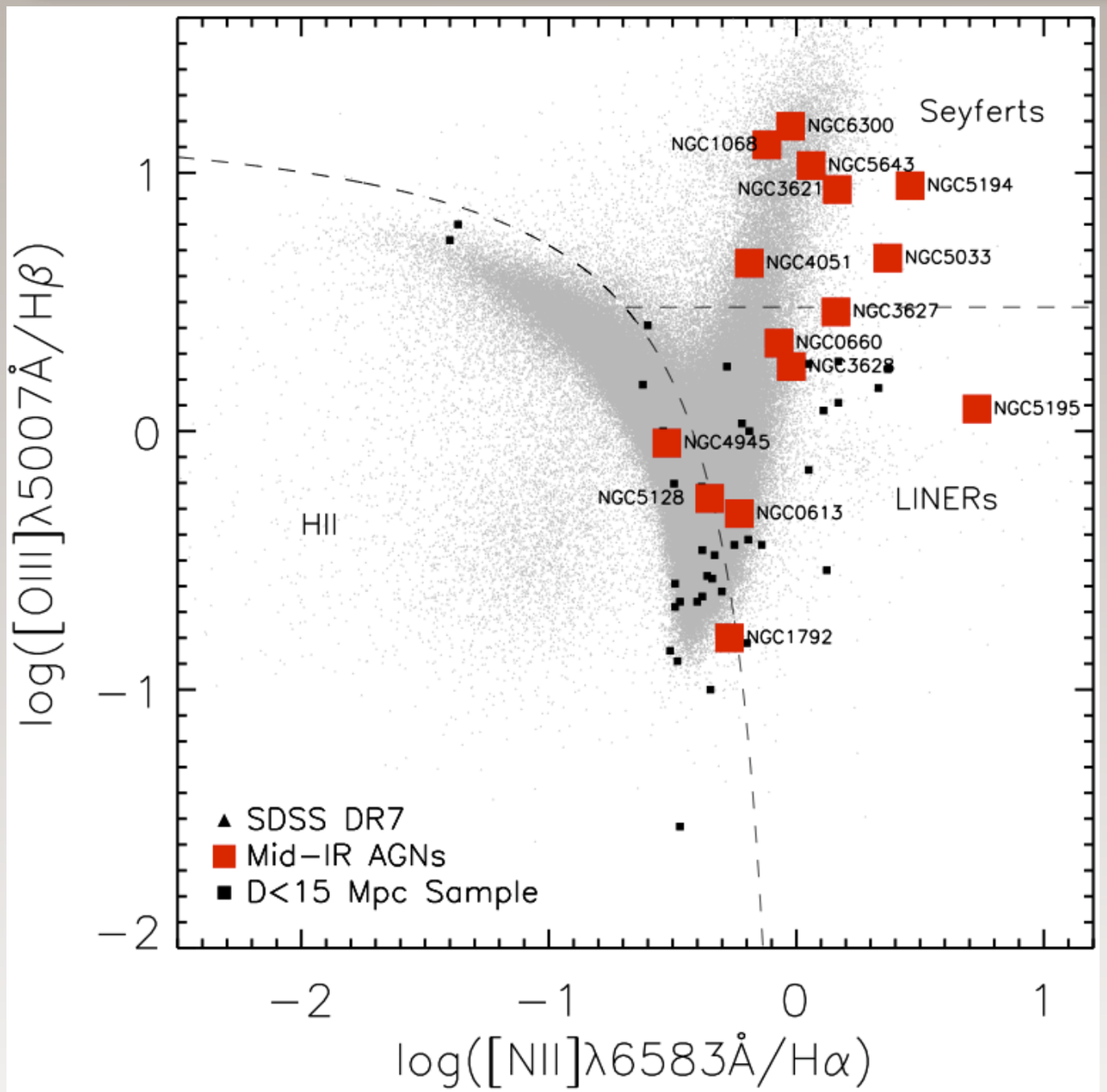
The Quest for a Complete Census of AGN Activity in the local Universe

- A Volume-Limited Sample
- Revised Bright Galaxy Survey (RBGS; Sanders *et al.* [2003])
- 68 IR-bright objects to D < 15Mpc - $L_{\rm IR} \gtrsim 3 \times 10^9 L_\odot$
- 64 with high-resolution *Spitzer*-IRS (~94% Complete)
- 17 / 64 galaxies with [NeV] and [OIV] detections... mid-IR AGN fraction : ~ 27±7%

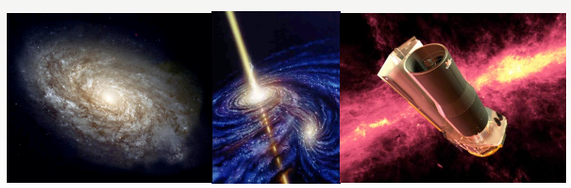




An Optically Obscured Population of AGNs (Goulding & Alexander 2009)



- Sensitive Optical studies (Ho et al. 1997):
  - ~ 10 % of local galaxies are Seyferts
  - Hosted in predominantly early-type systems (E - Sbc)
- Optical AGN detection depends strongly on morphological type (< 20 % in Sc or later)
- Sensitive Mid-Infrared spectroscopy:
  - ~27% of local galaxies are Seyferts
  - Many reside in late-type spirals (Sc-Sd)



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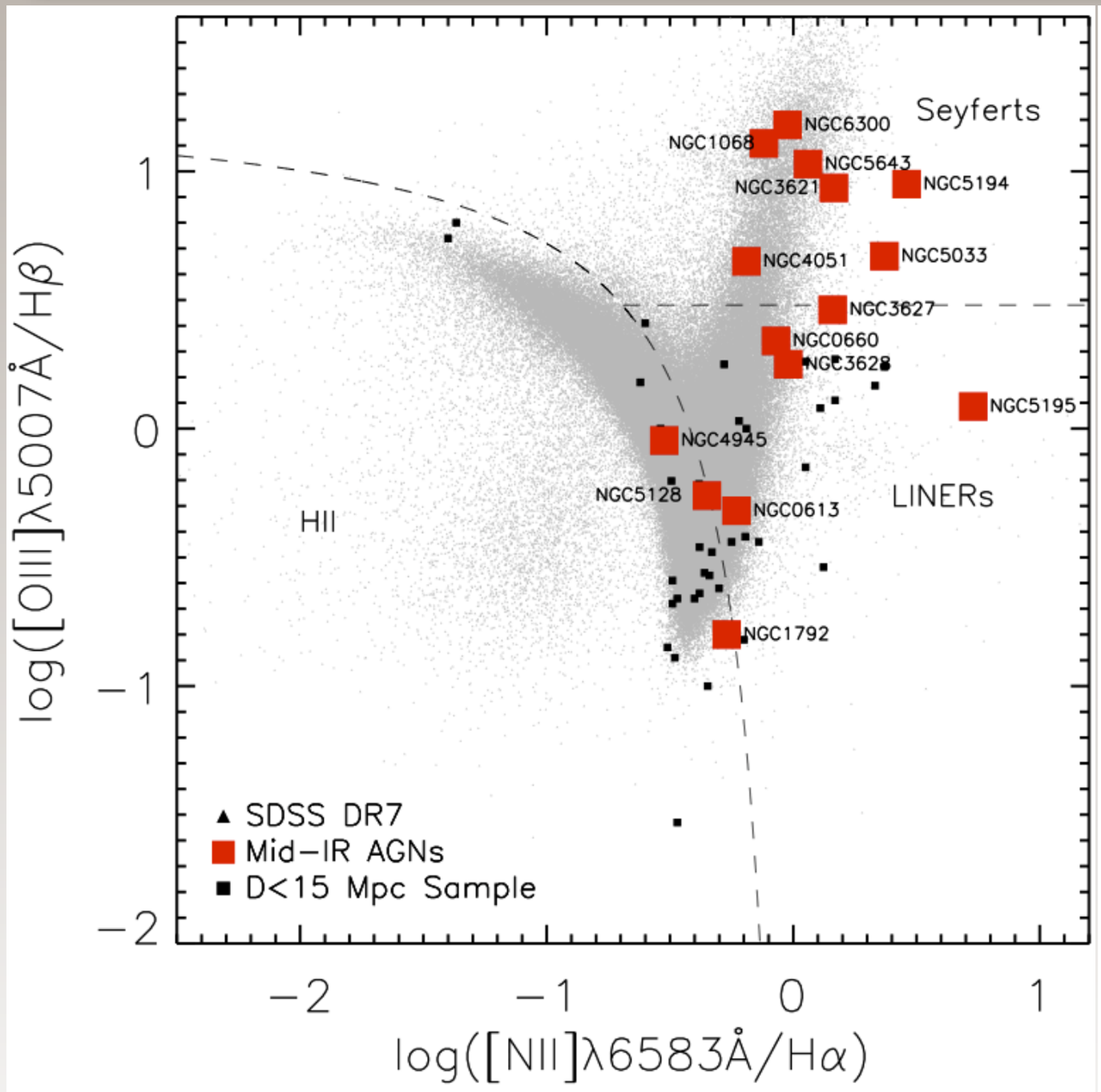

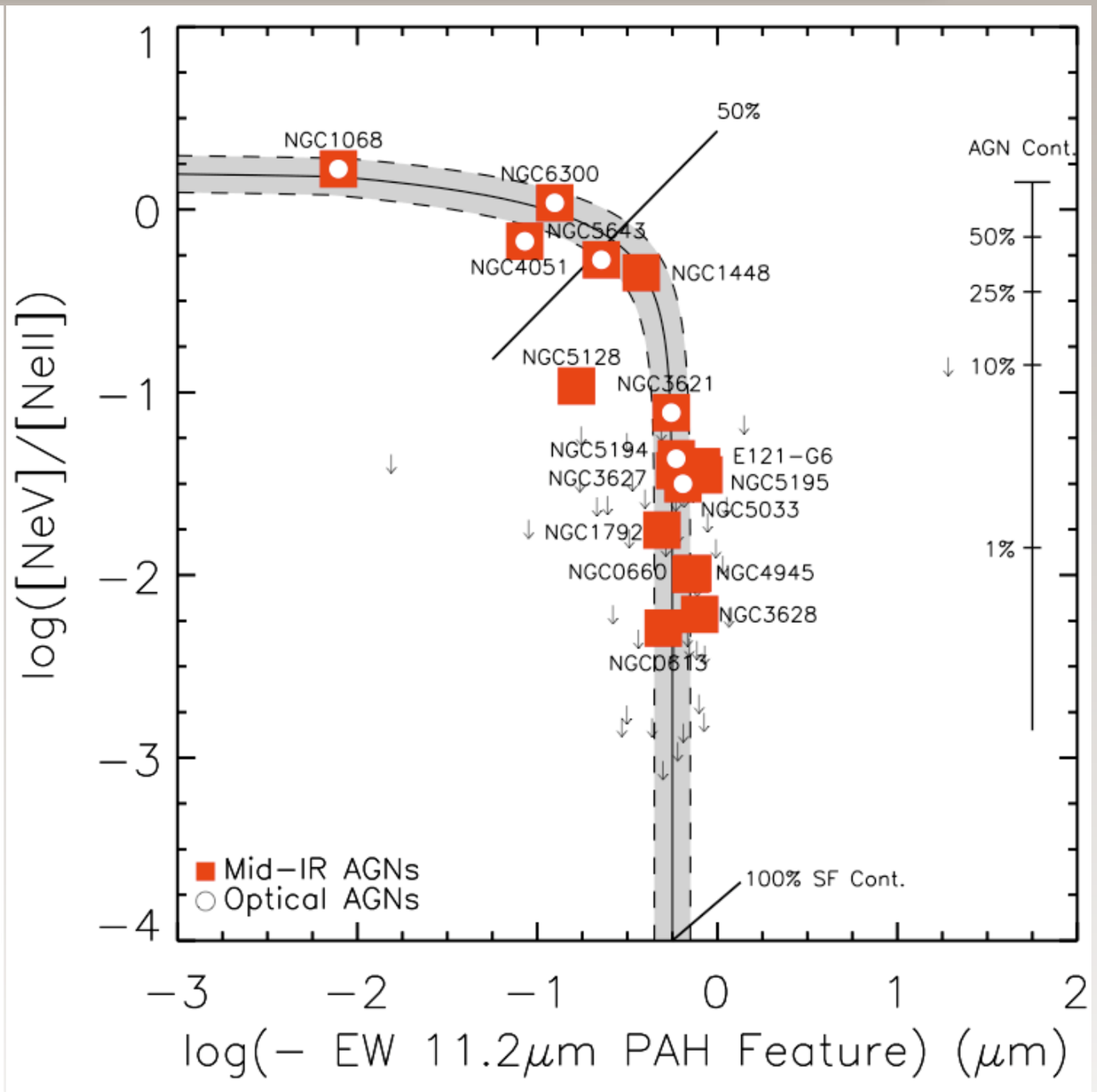

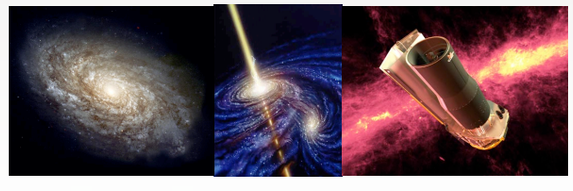

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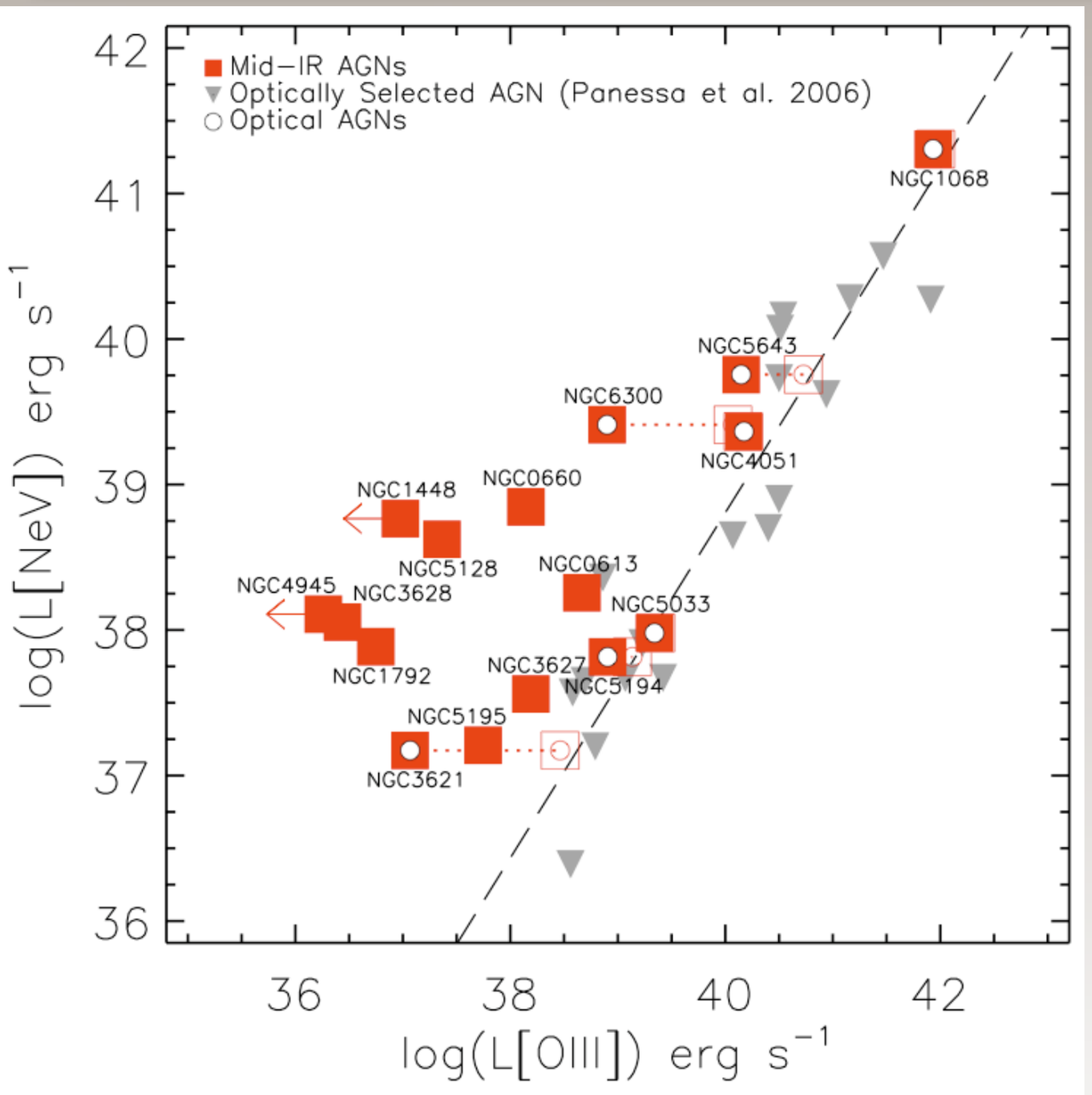

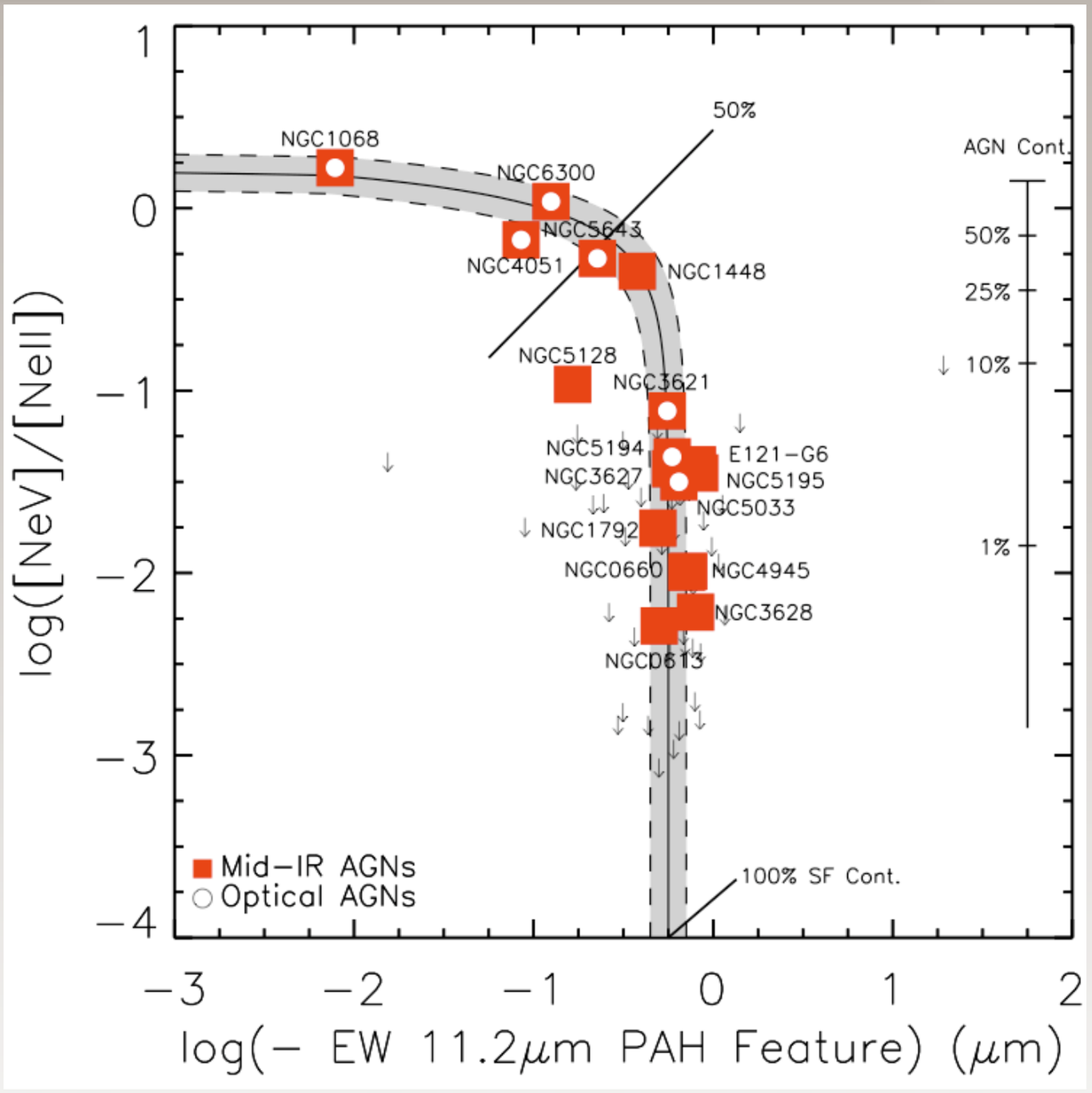

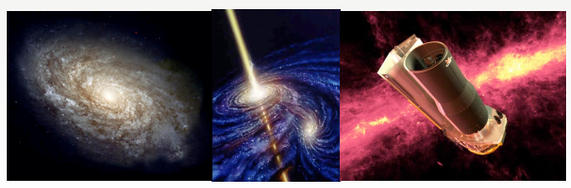

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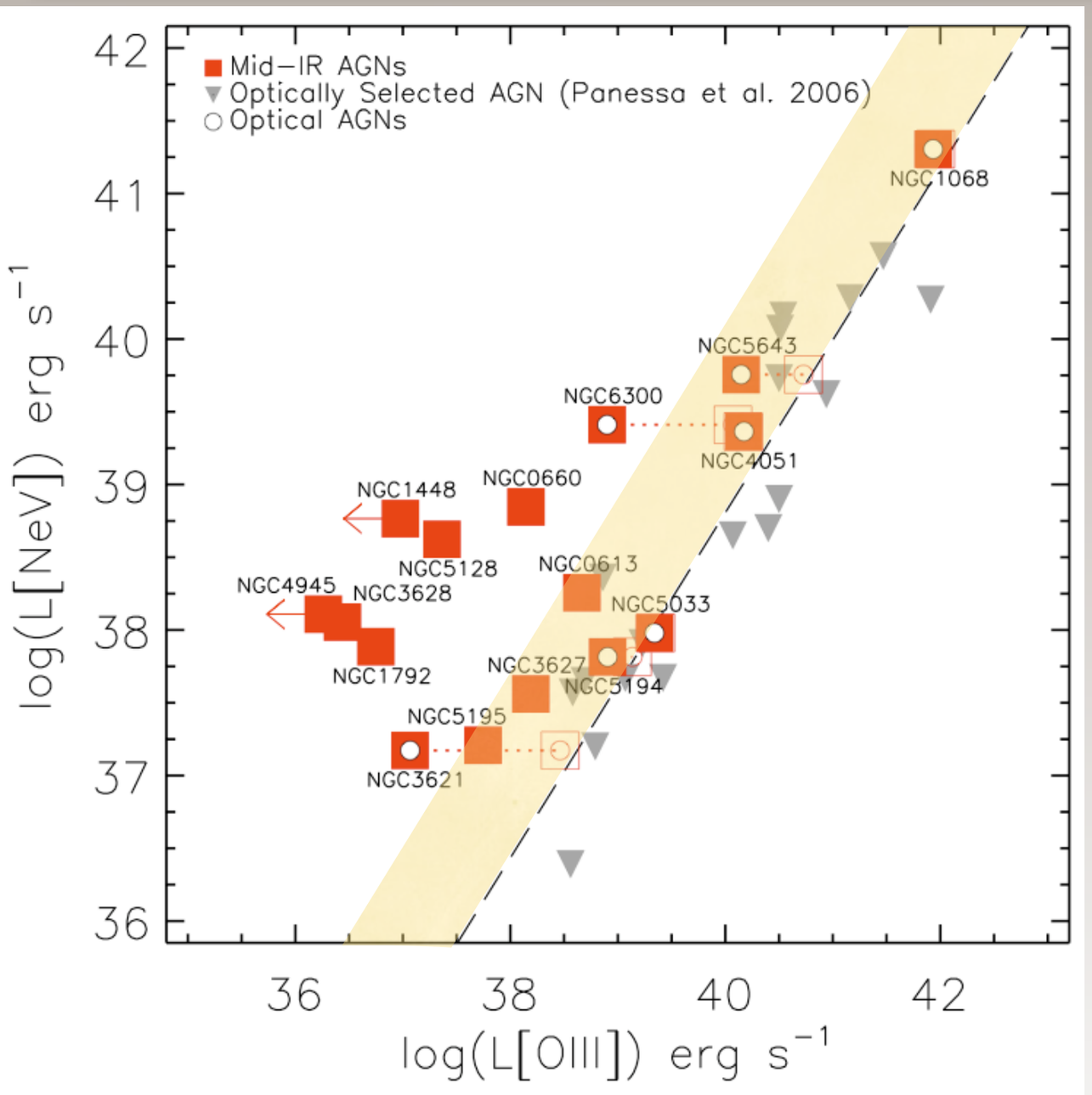
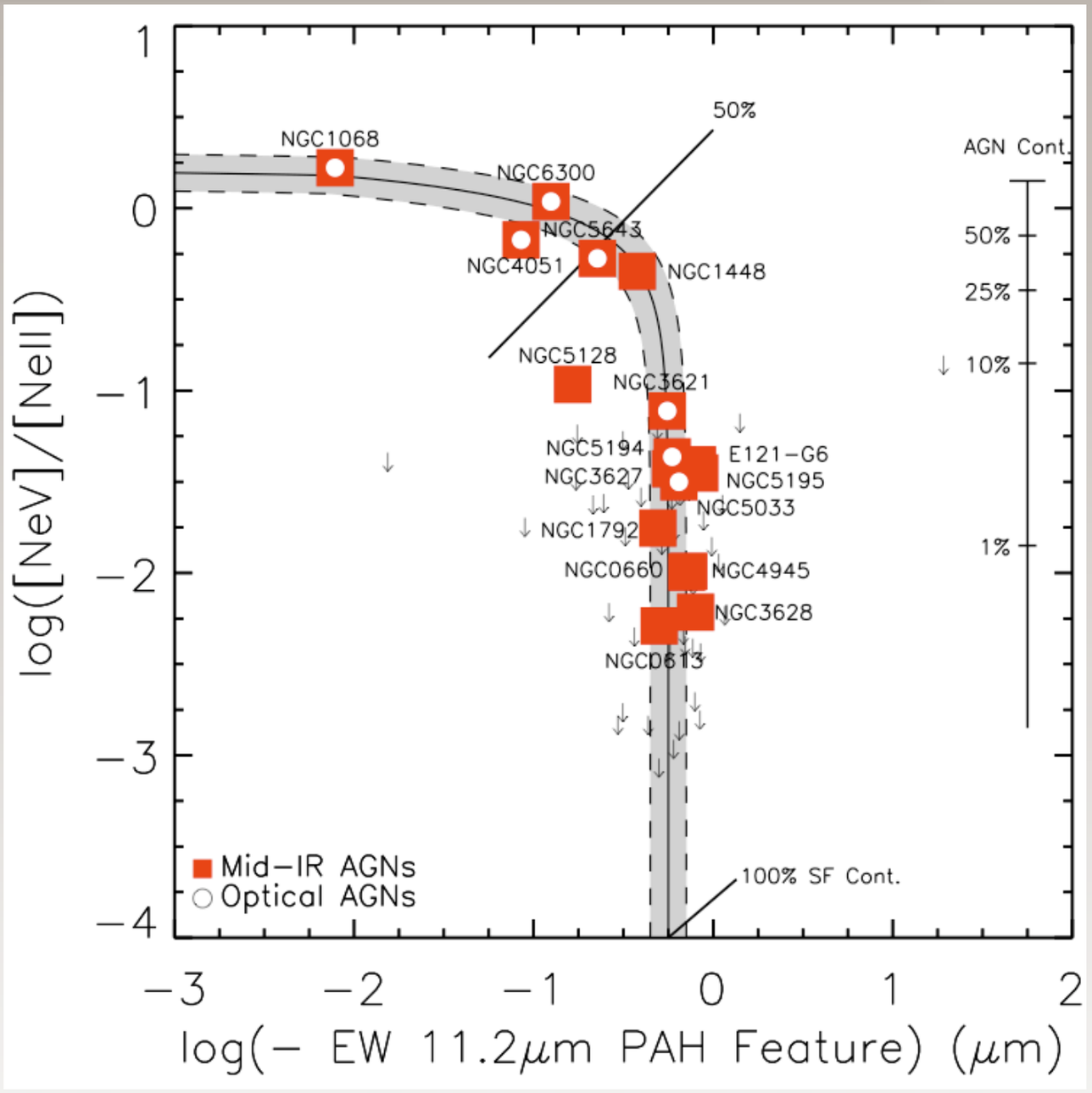
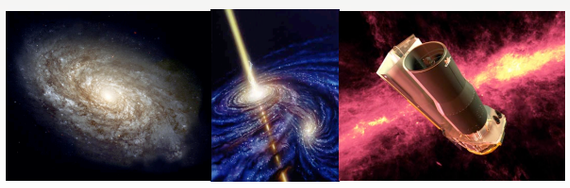
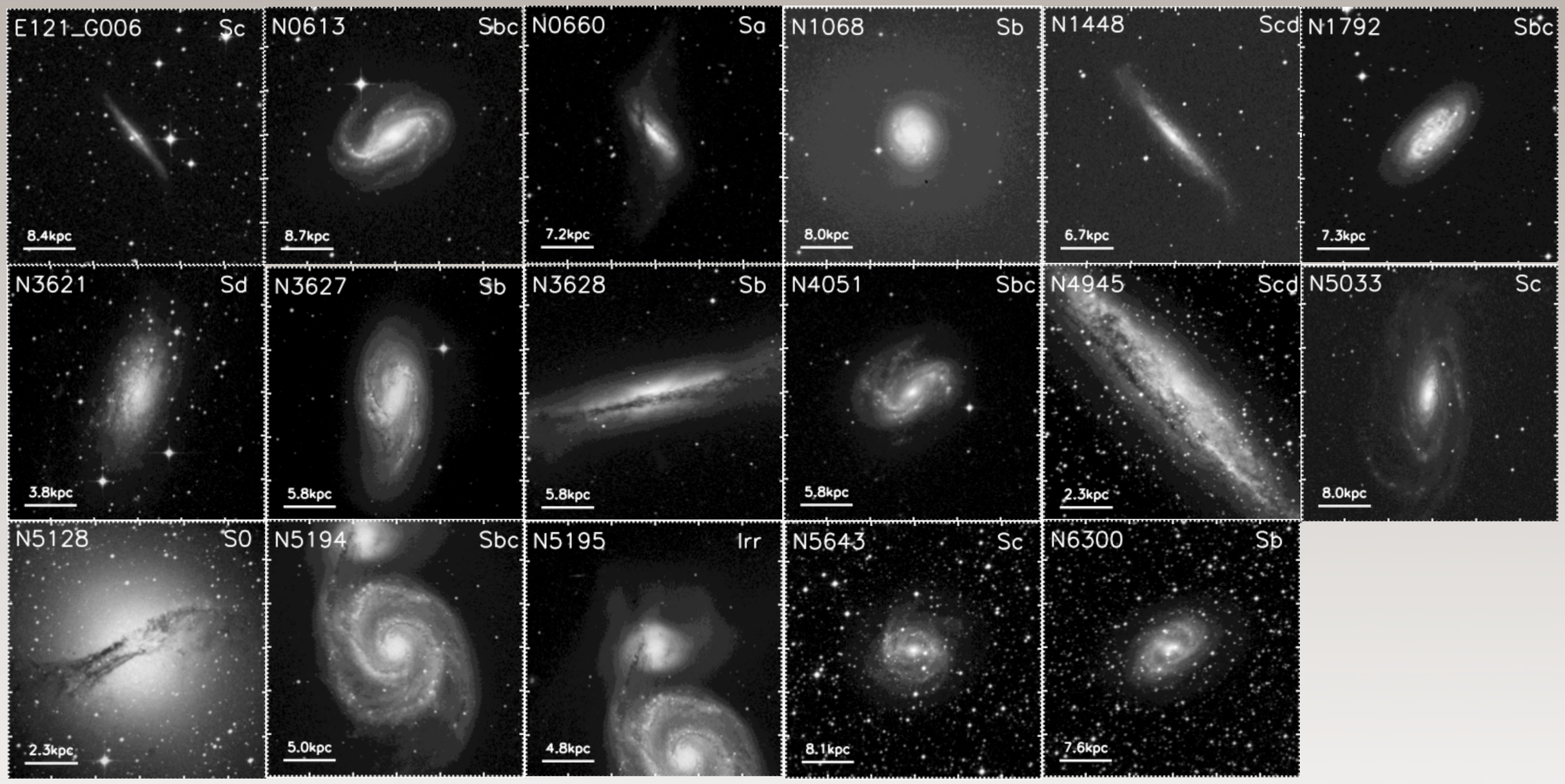
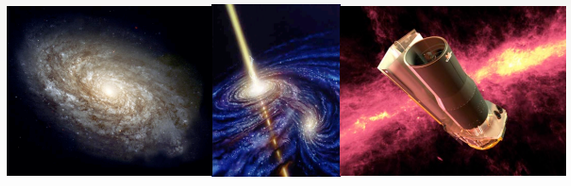






Extinction in the Host Galaxy?





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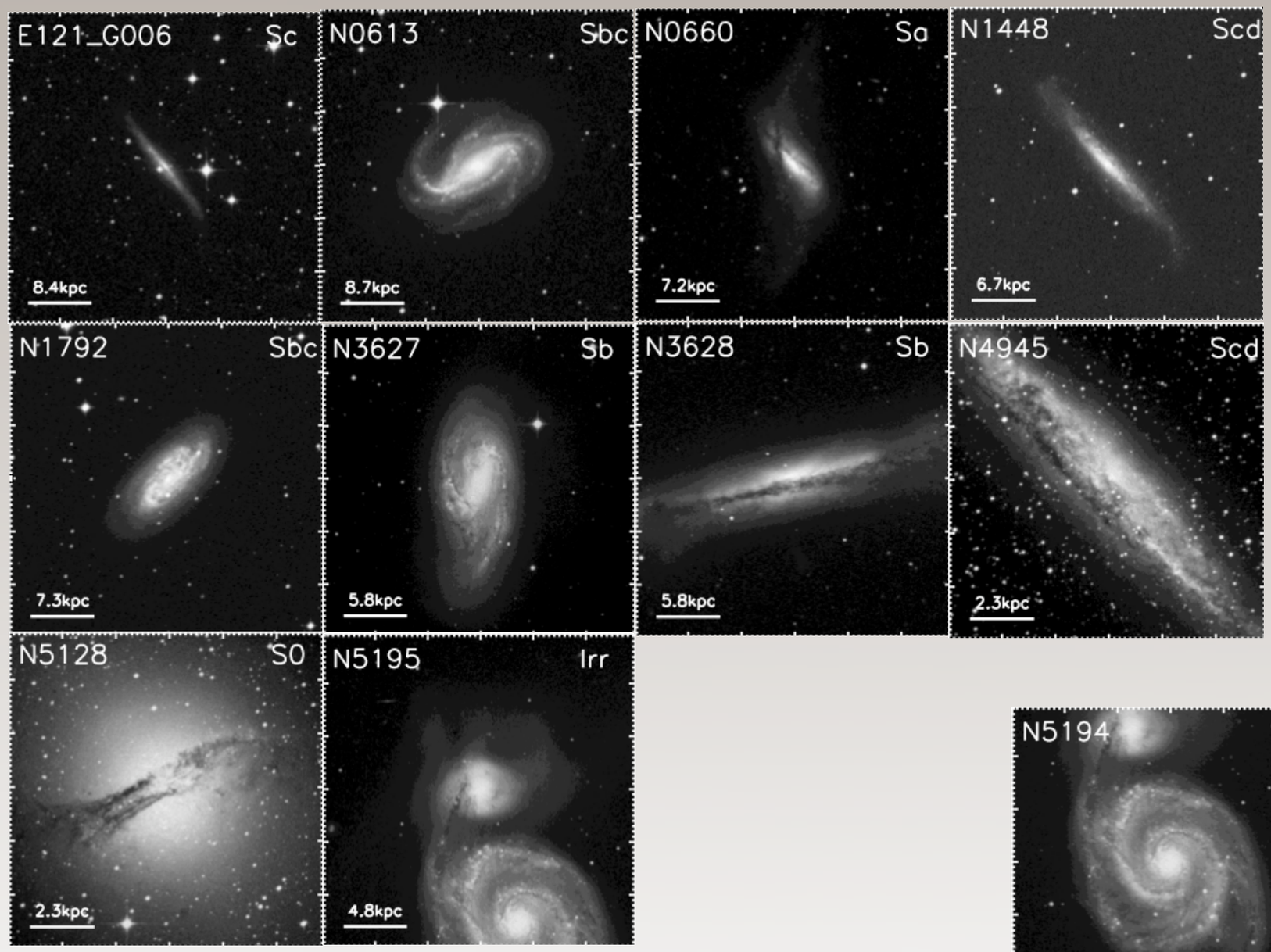
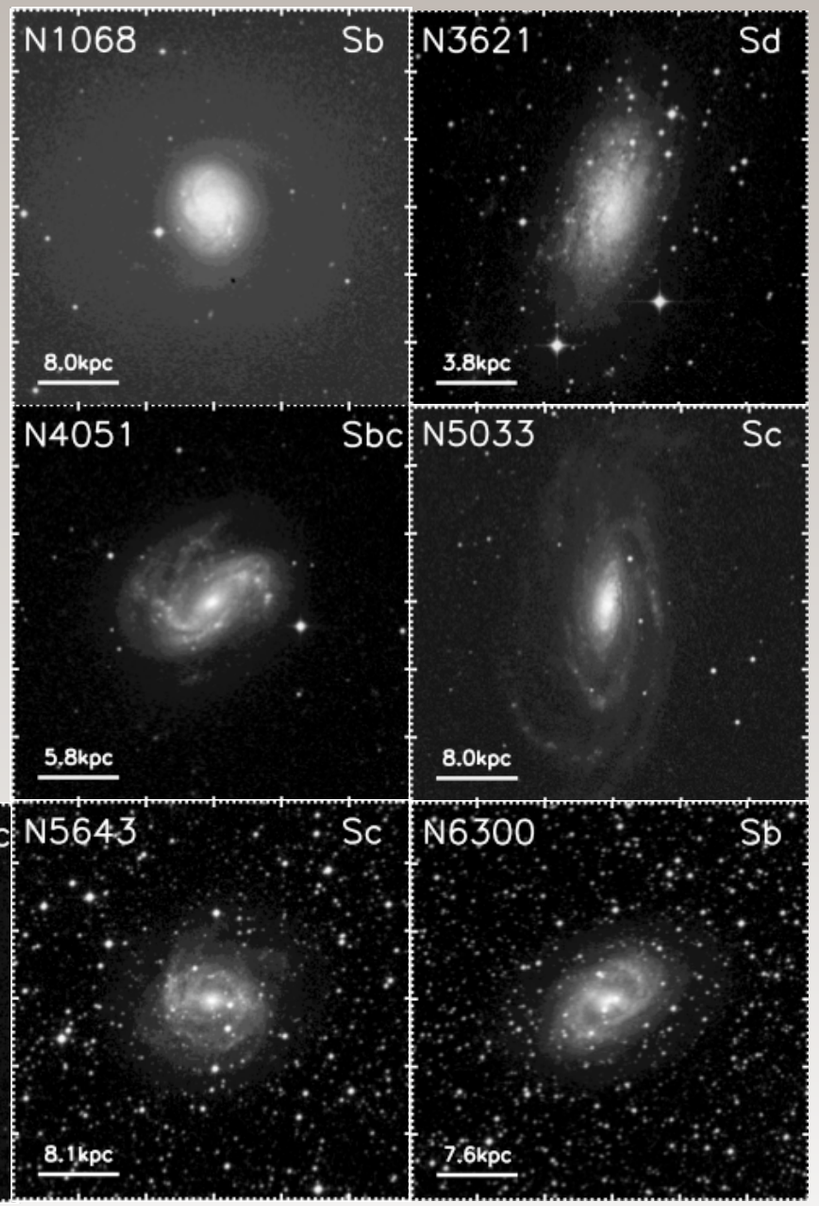
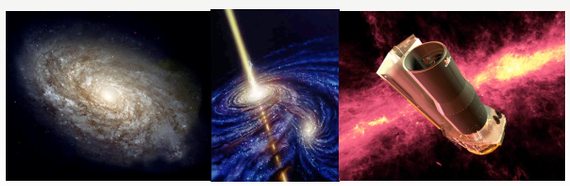


Optically Unidentified AGNs

Optical Seyferts





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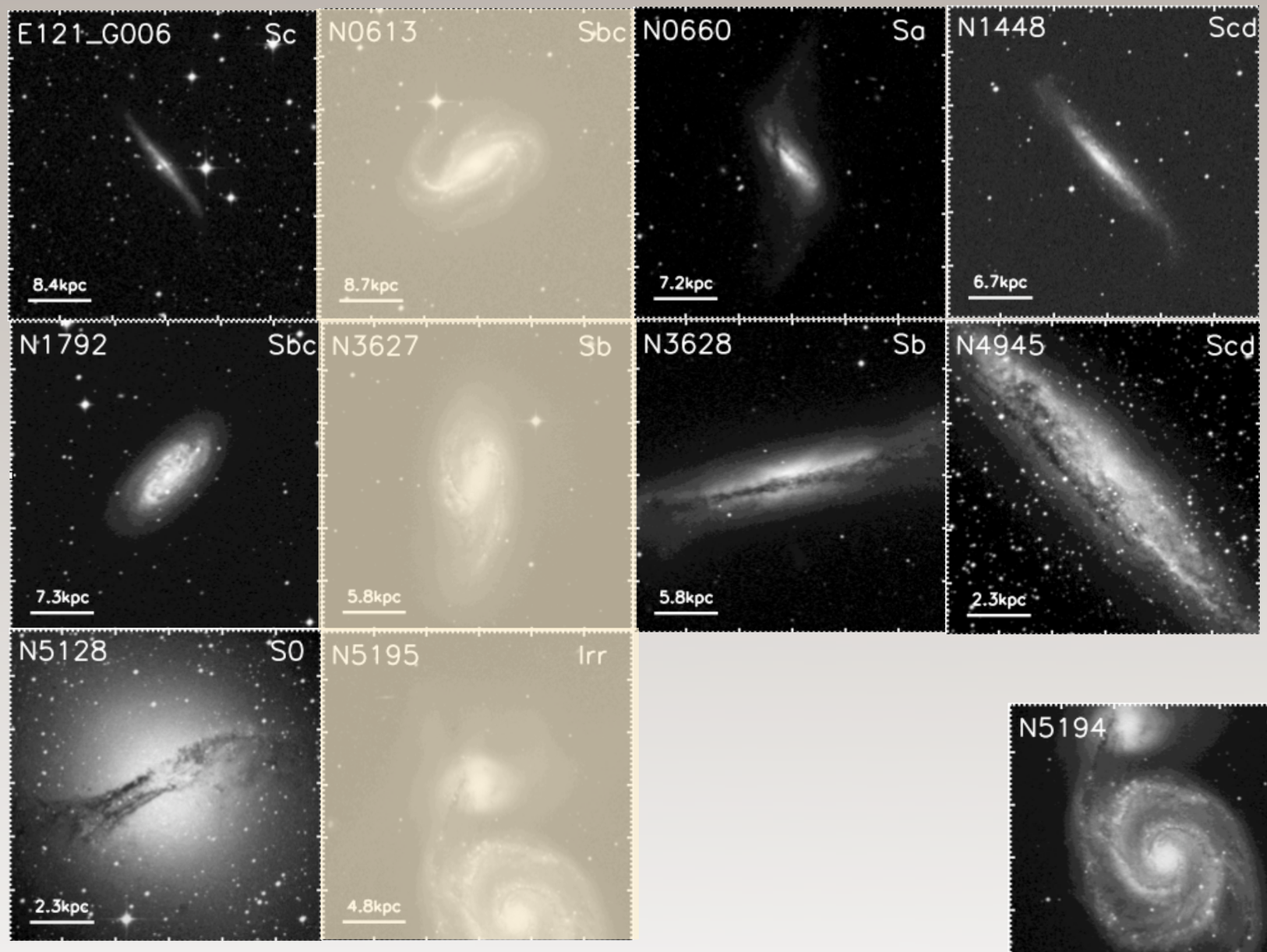

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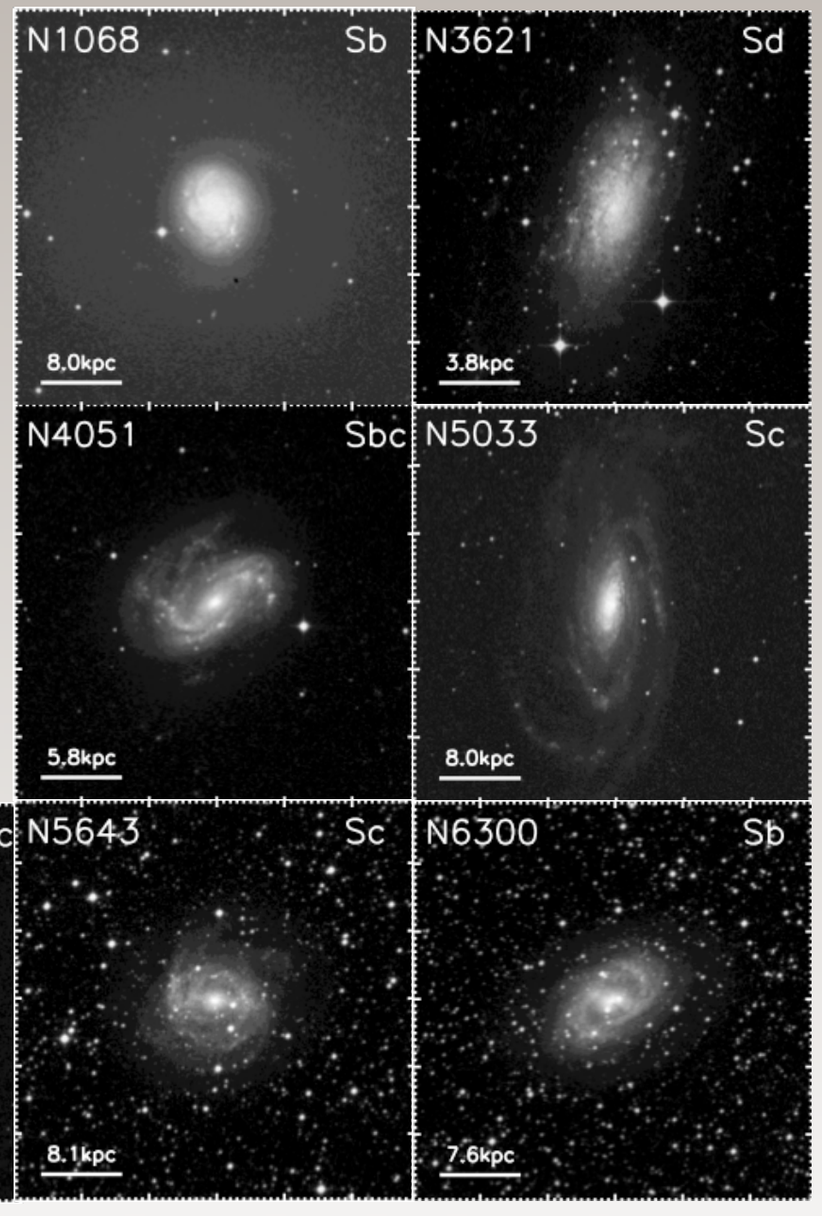
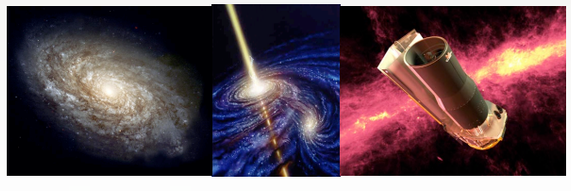
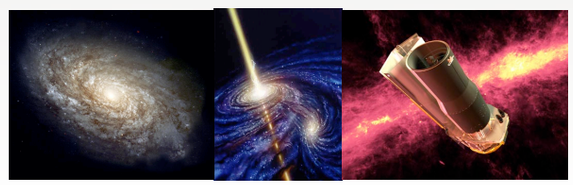




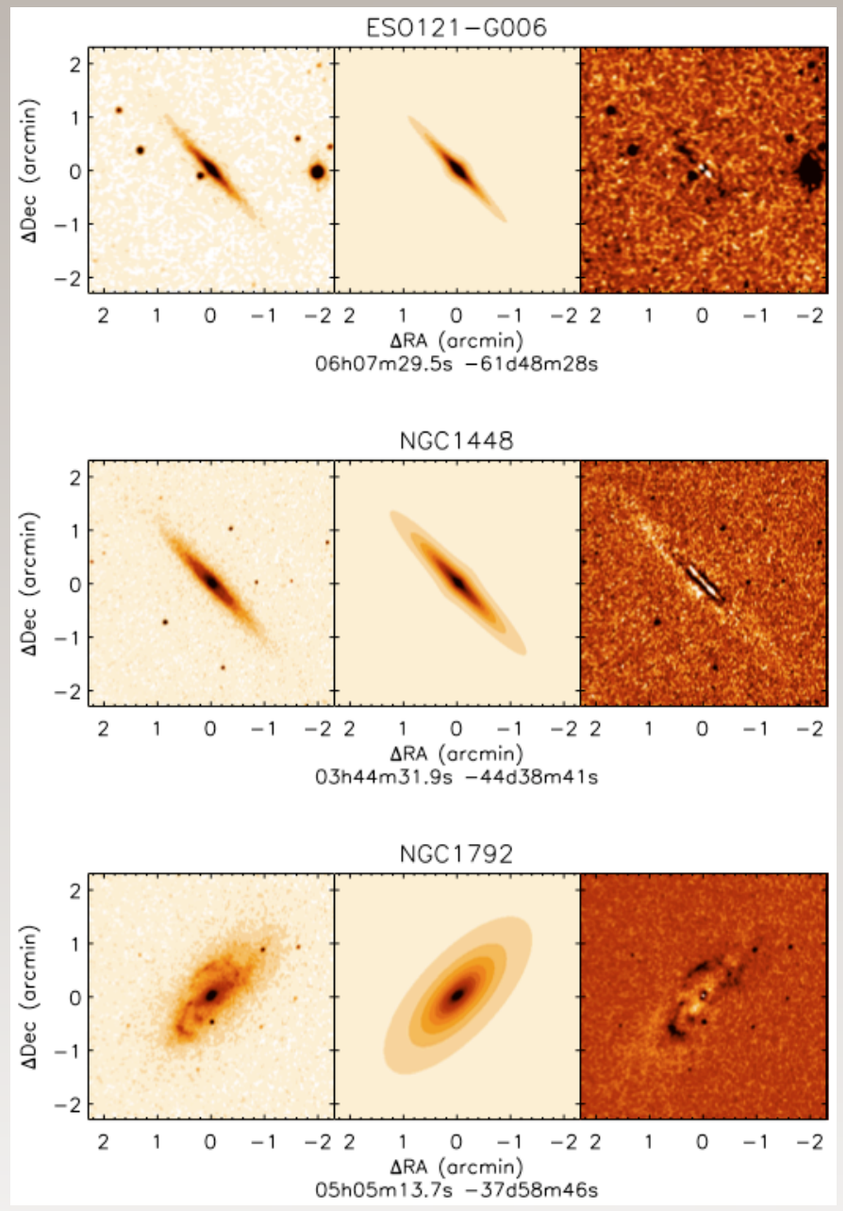
The Main Outstanding Questions

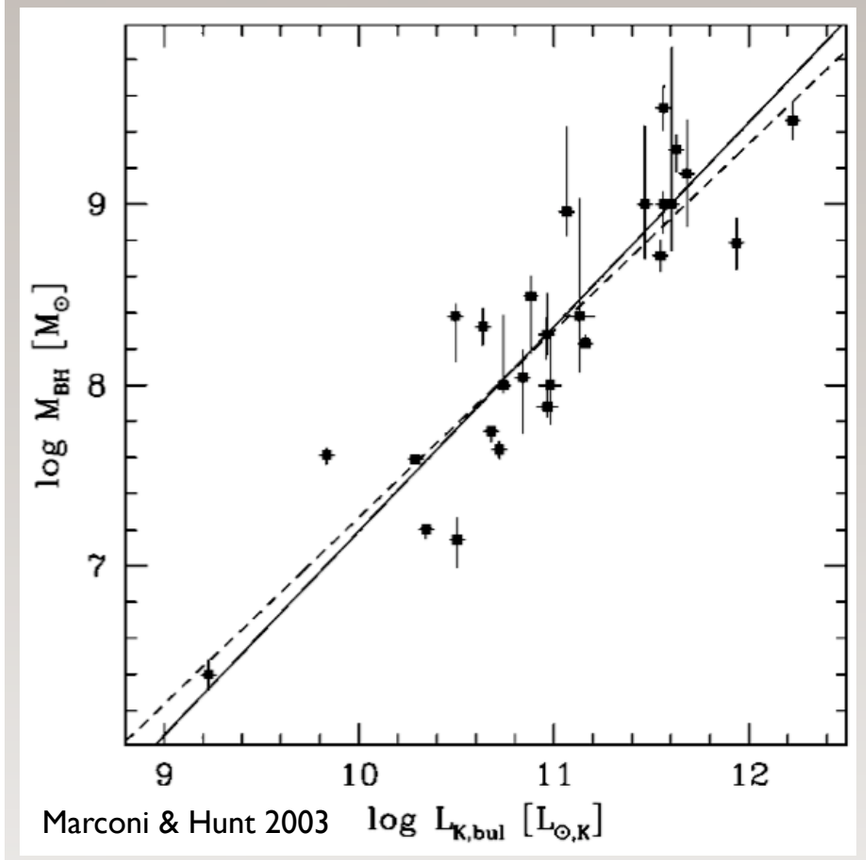
1) **How rapidly are the SMBHs accreting?**
2) **What does this imply for the present-day growth of SMBHs?**
3) **How does this change the observed space density of active SMBHs?**



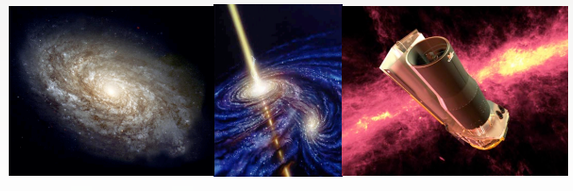
Mass Estimations of the SMBHs

- Physical AGN Science:
  - Reverberation mapping - 1
  - Maser mapping - 2
  - Gas Dynamics - 1
- In-direct Estimations:
  - M-σ relation - 10
  - M_{BH} - $L_{K,bul}$ - 3
- GALFIT bulge/disc decomposition for the 3 galaxies without previously published M_{BH} estimations

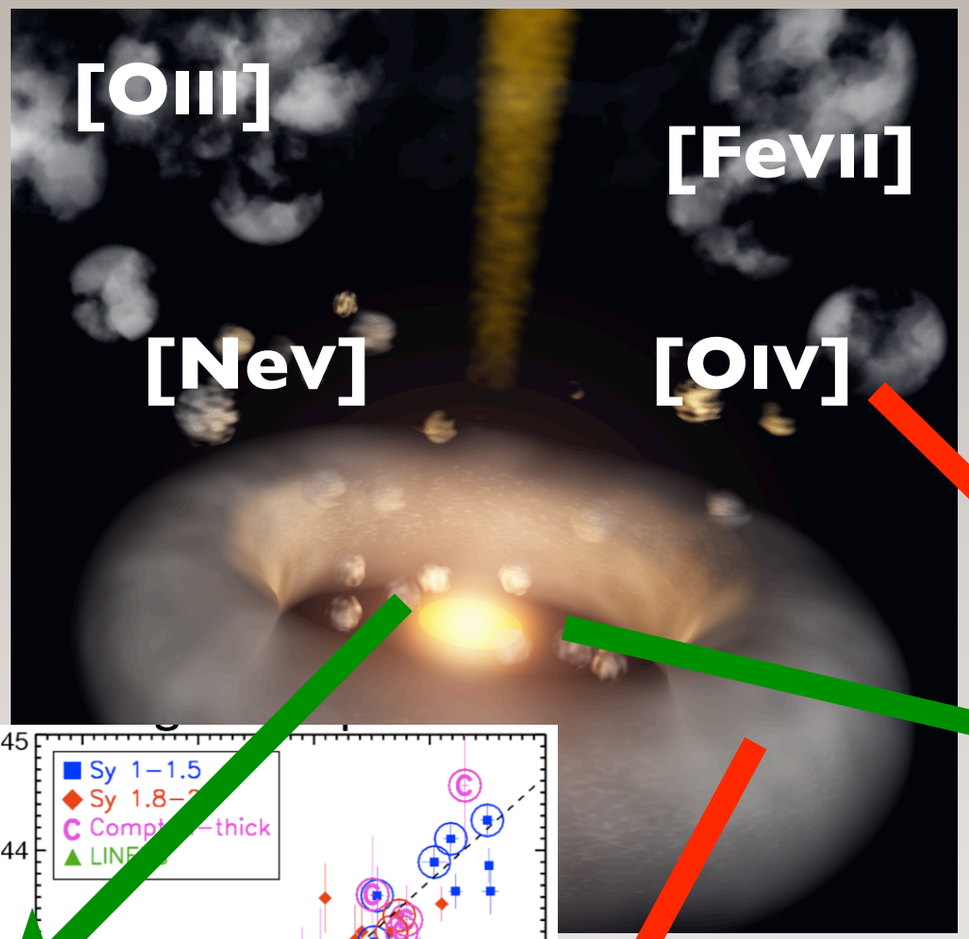


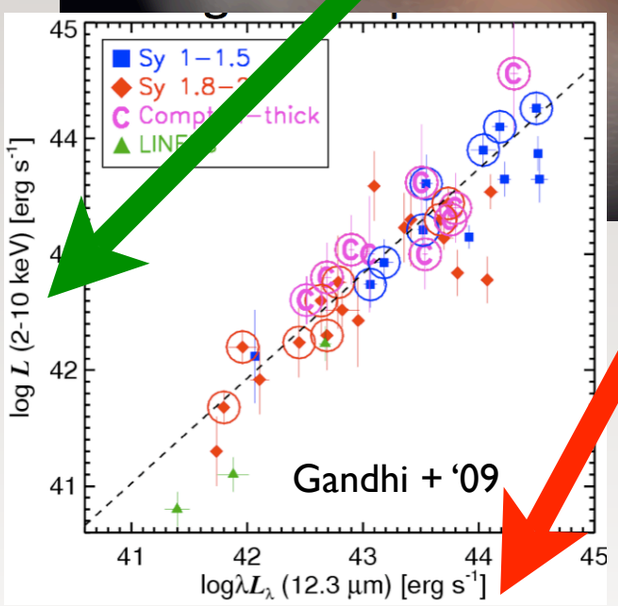


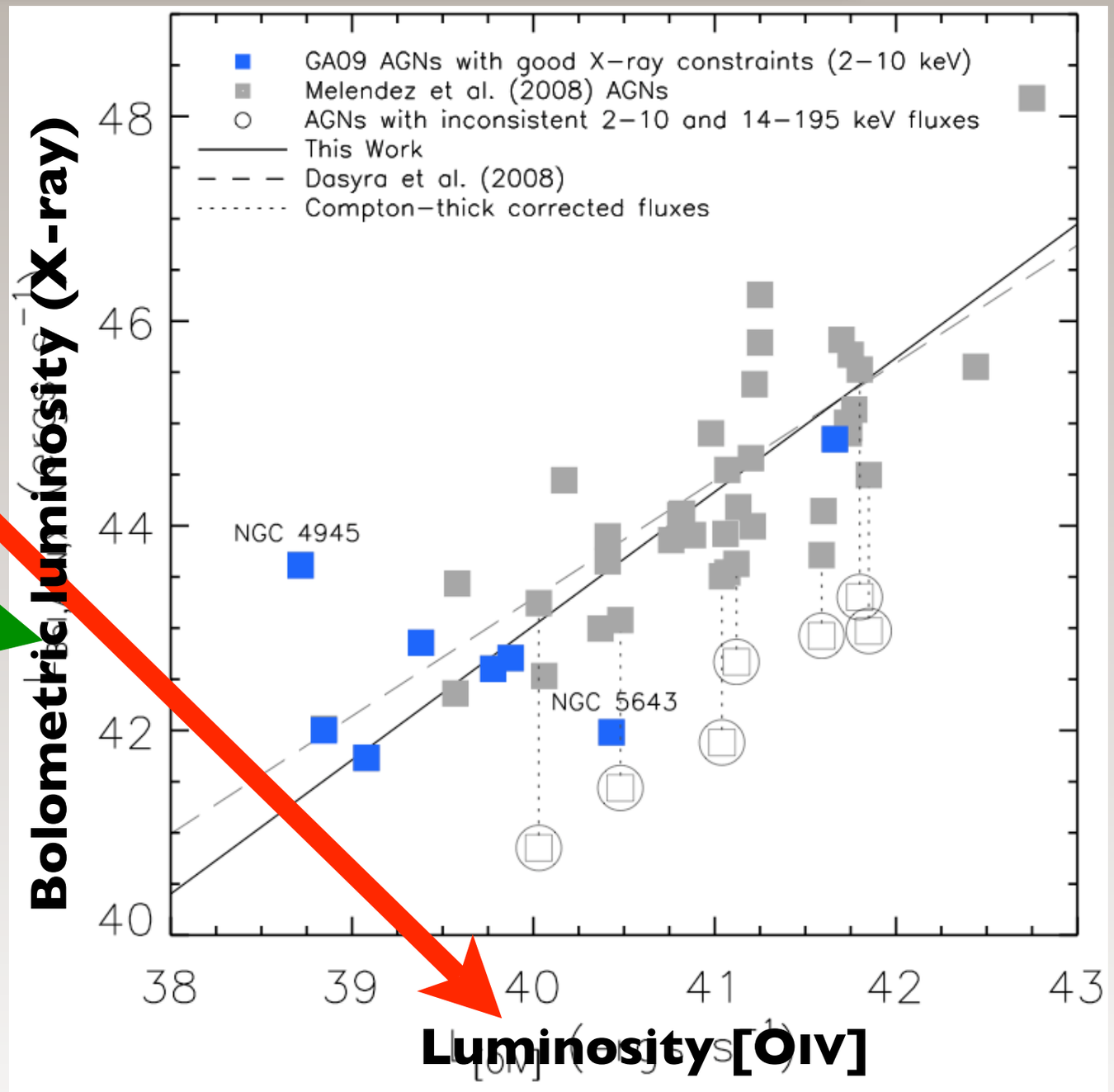
Marconi & Hunt 2003

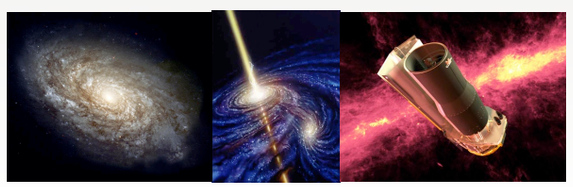


Intrinsic Luminosity of the AGNs





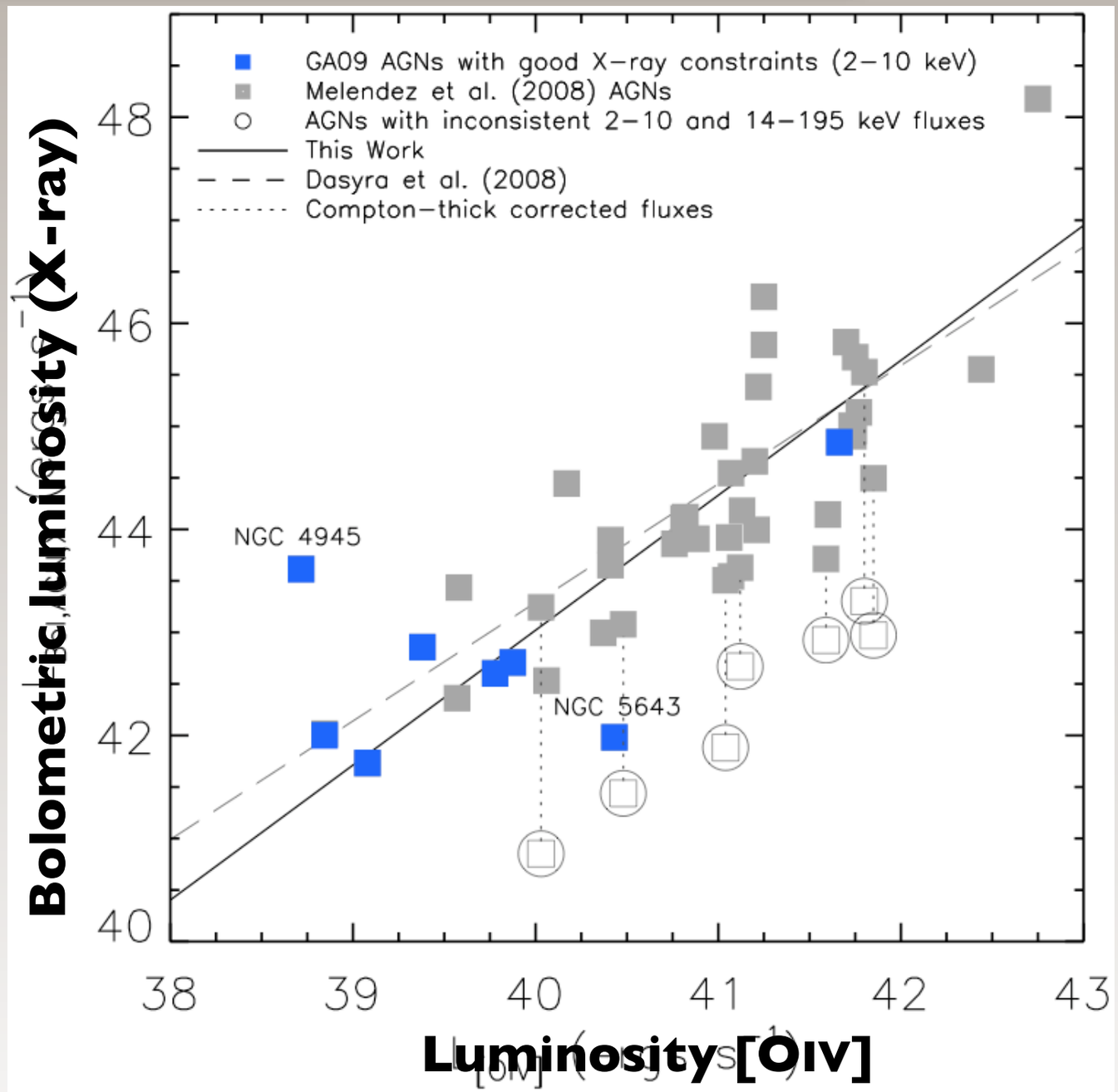


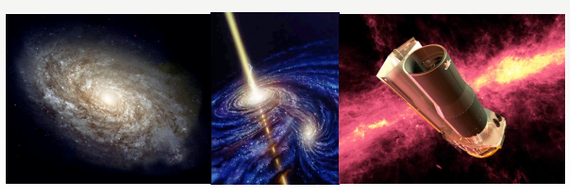


Intrinsic Luminosity of the AGNs

D < 15 Mpc AGN sample breakdown...

- 8 AGNs with excellent hard X-ray constraints (E > 10 keV)
- 5 AGNs poorly constrained at E < 8 keV
- 4 AGNs currently with no published X-ray constraints, but now have available data
- Luminosity of [O IV] as an indirect measure of AGN intrinsic luminosity...the need for good hard X-ray constraints





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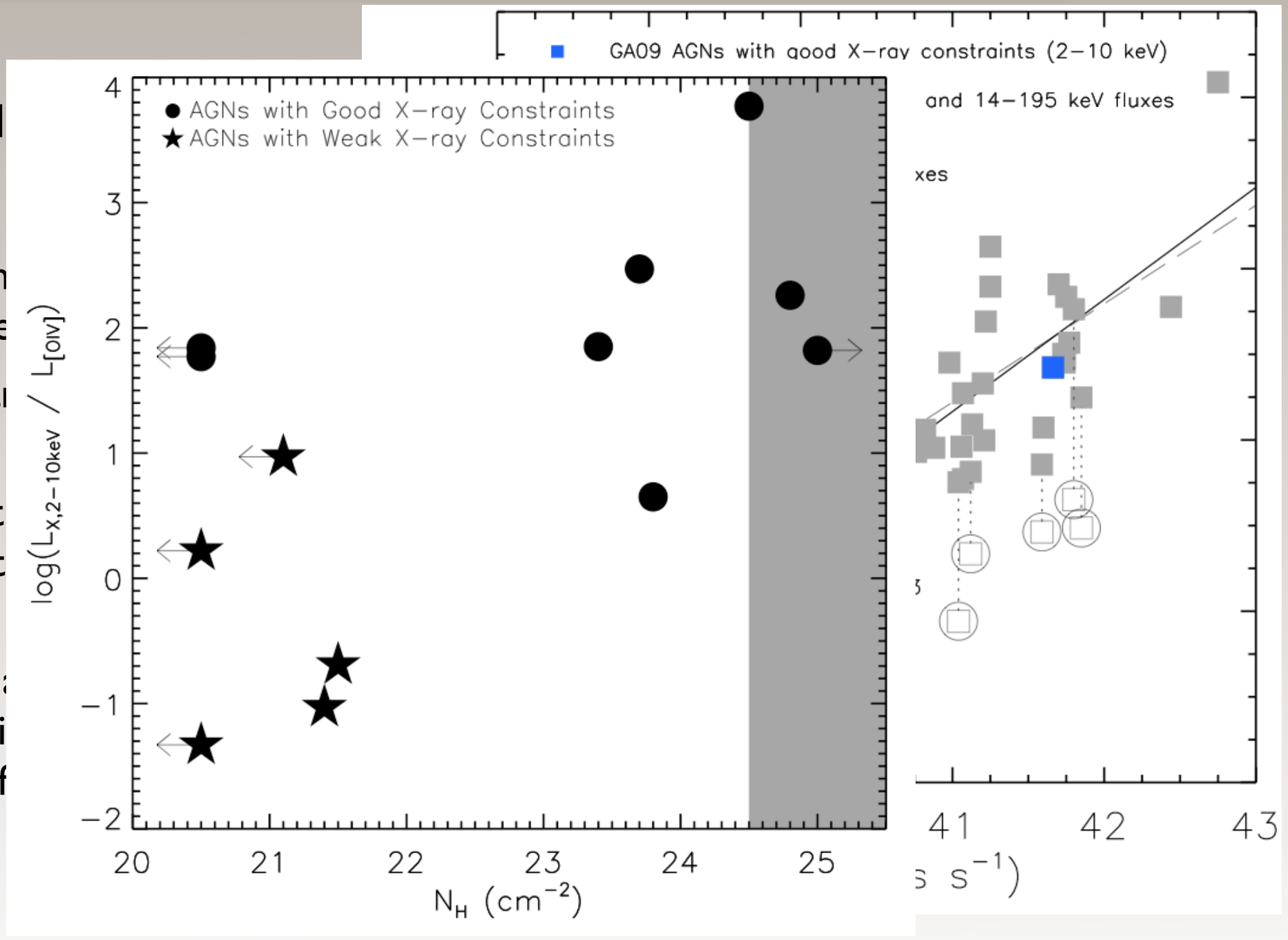

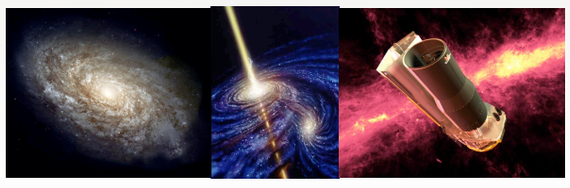

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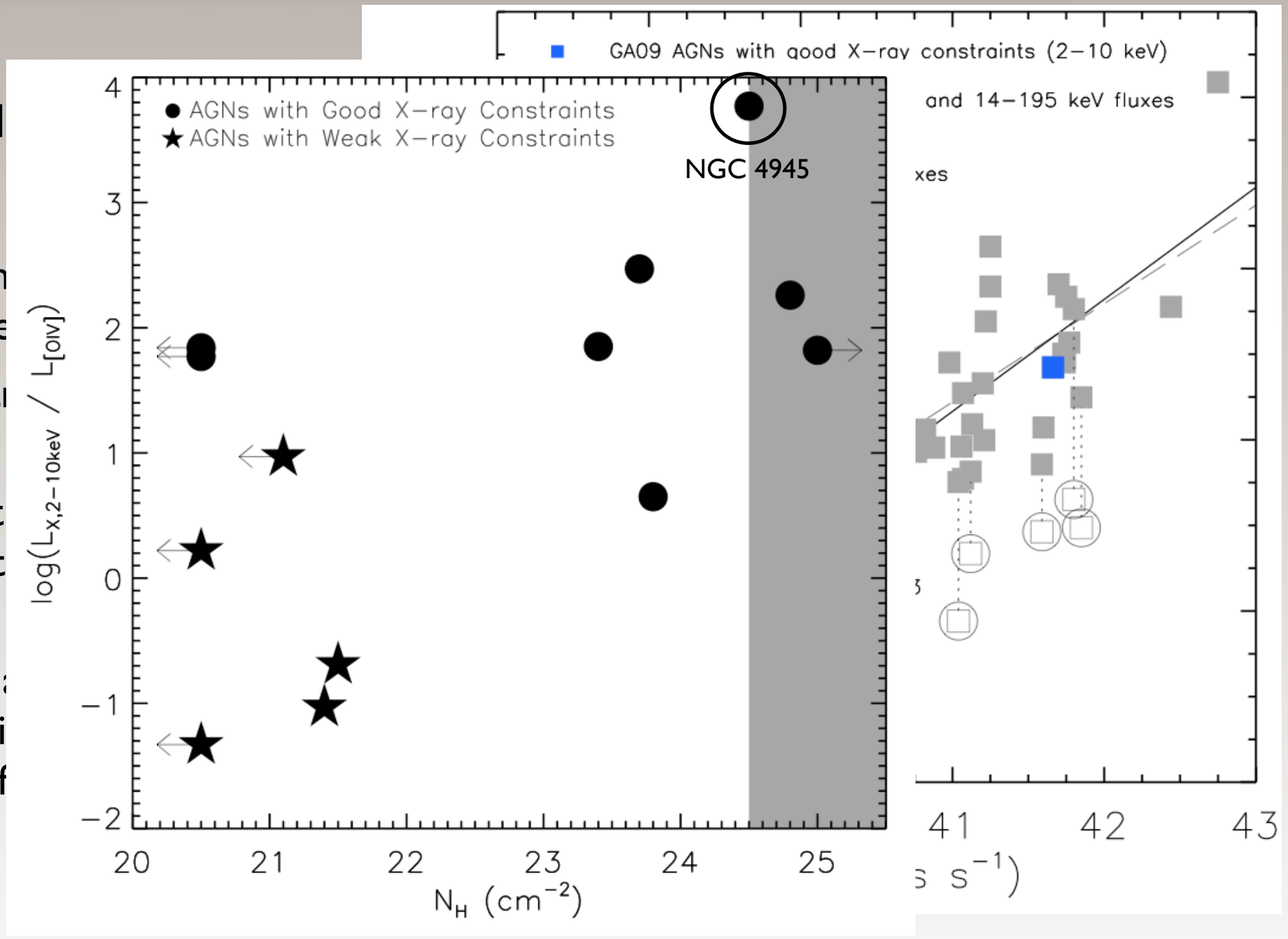

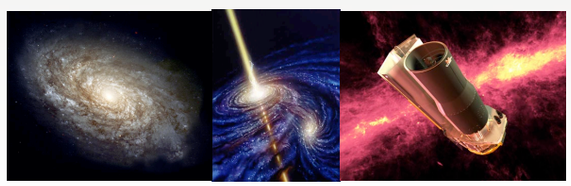

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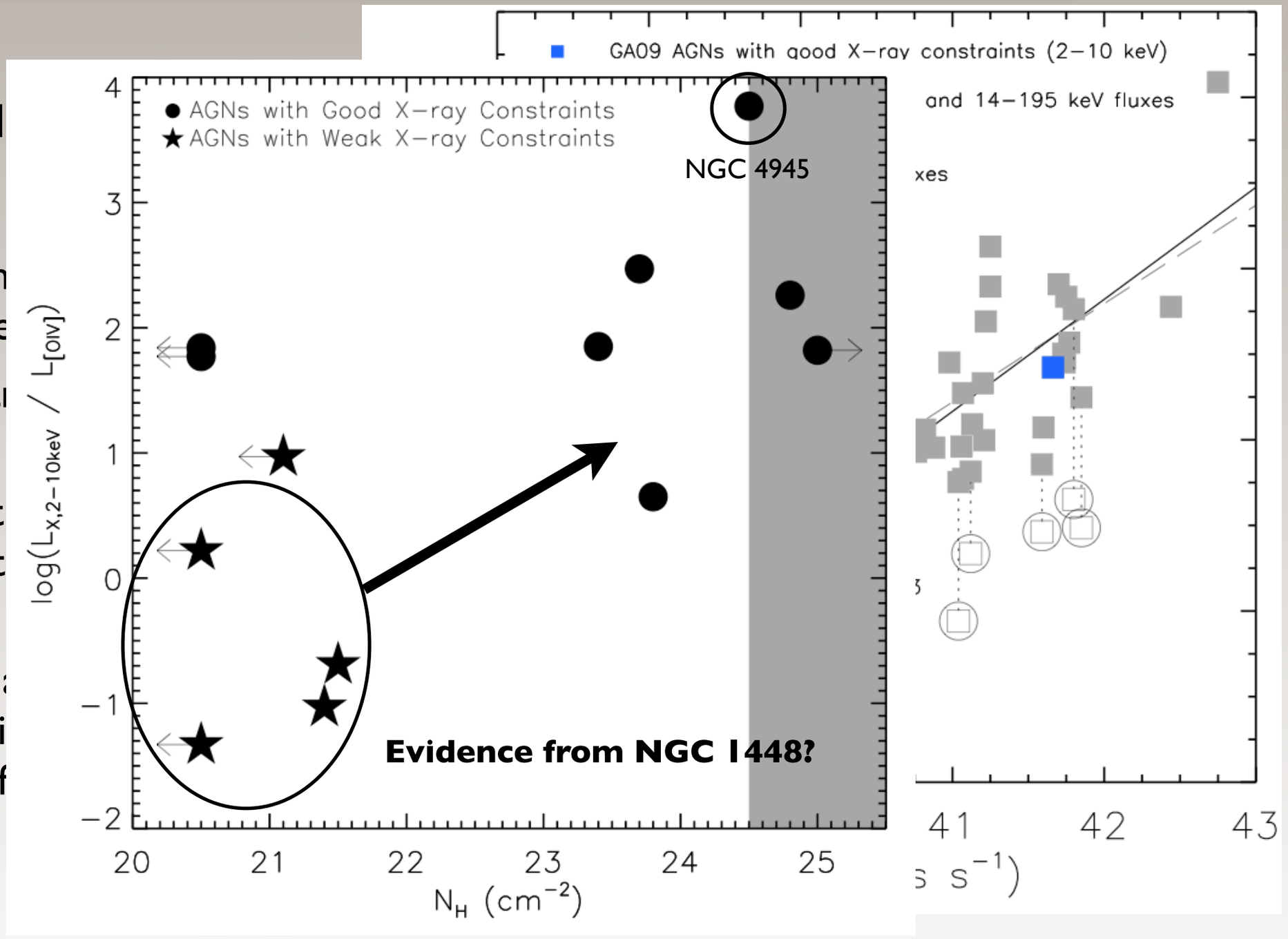

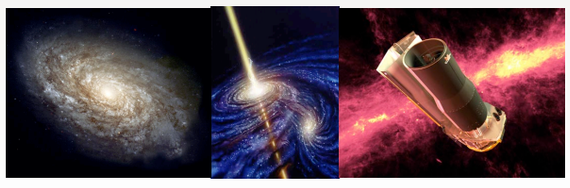

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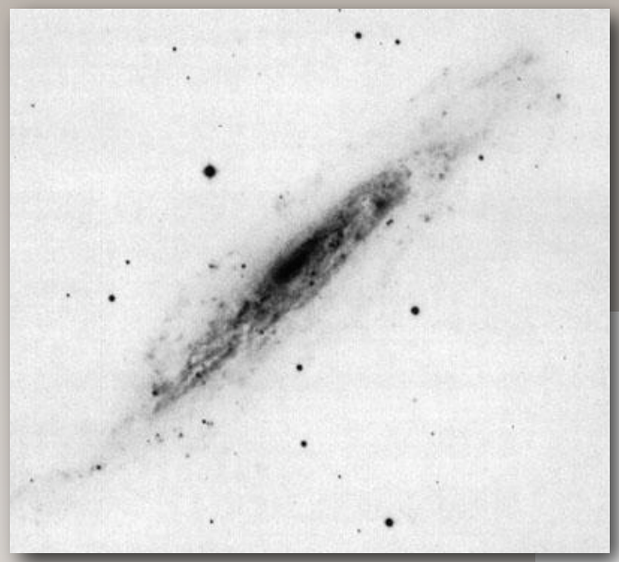
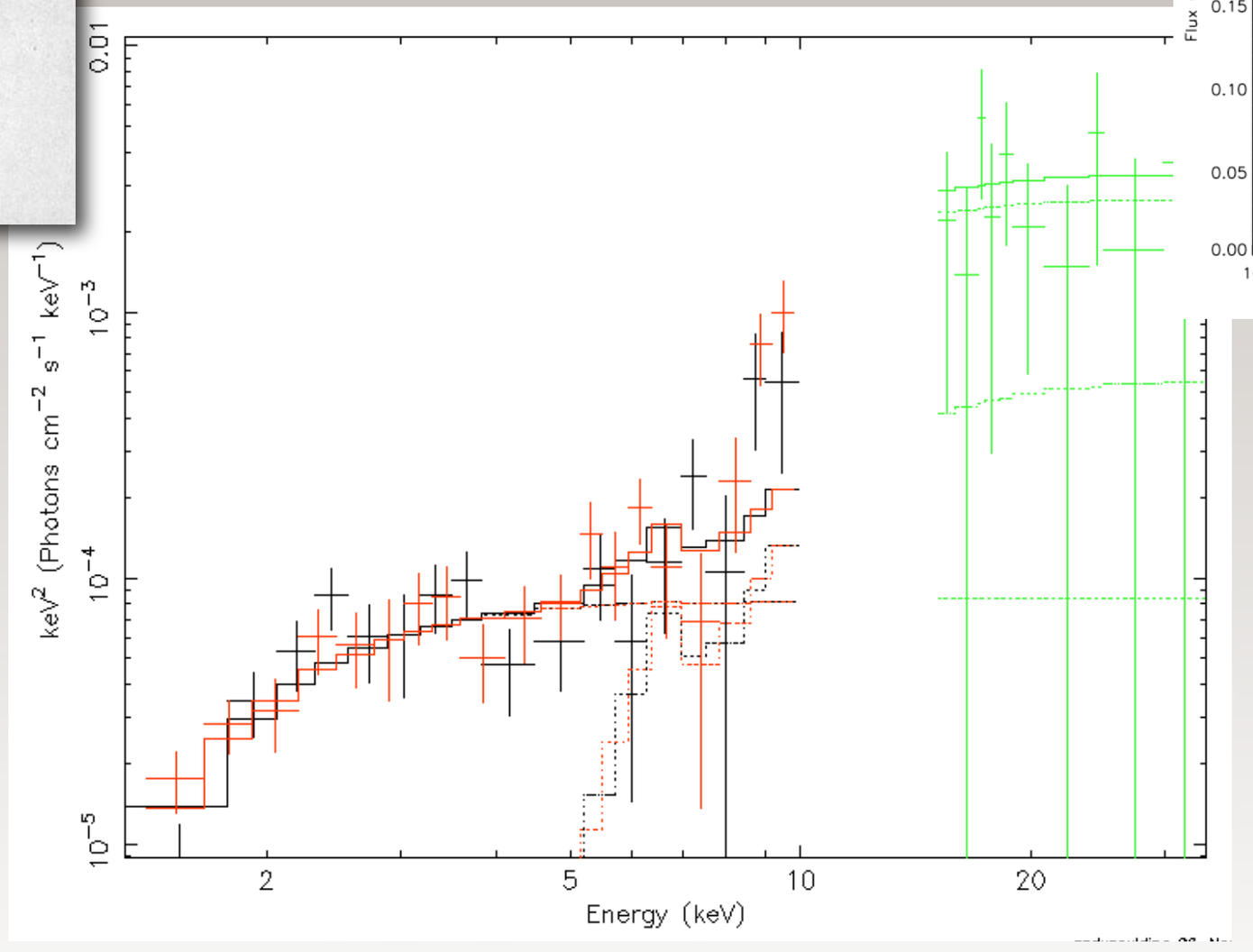
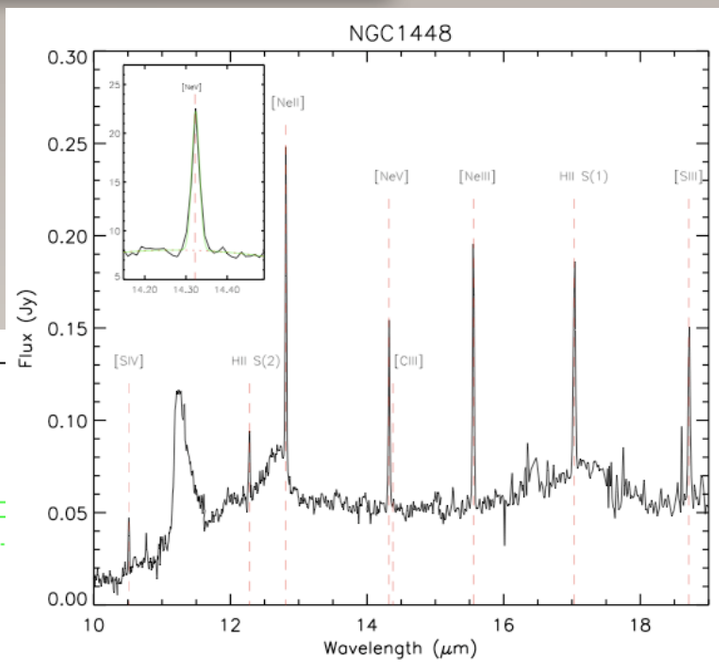
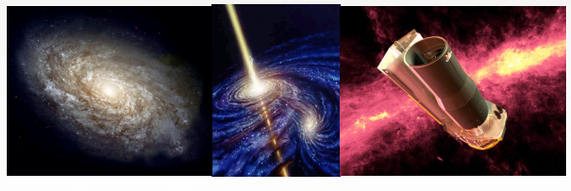






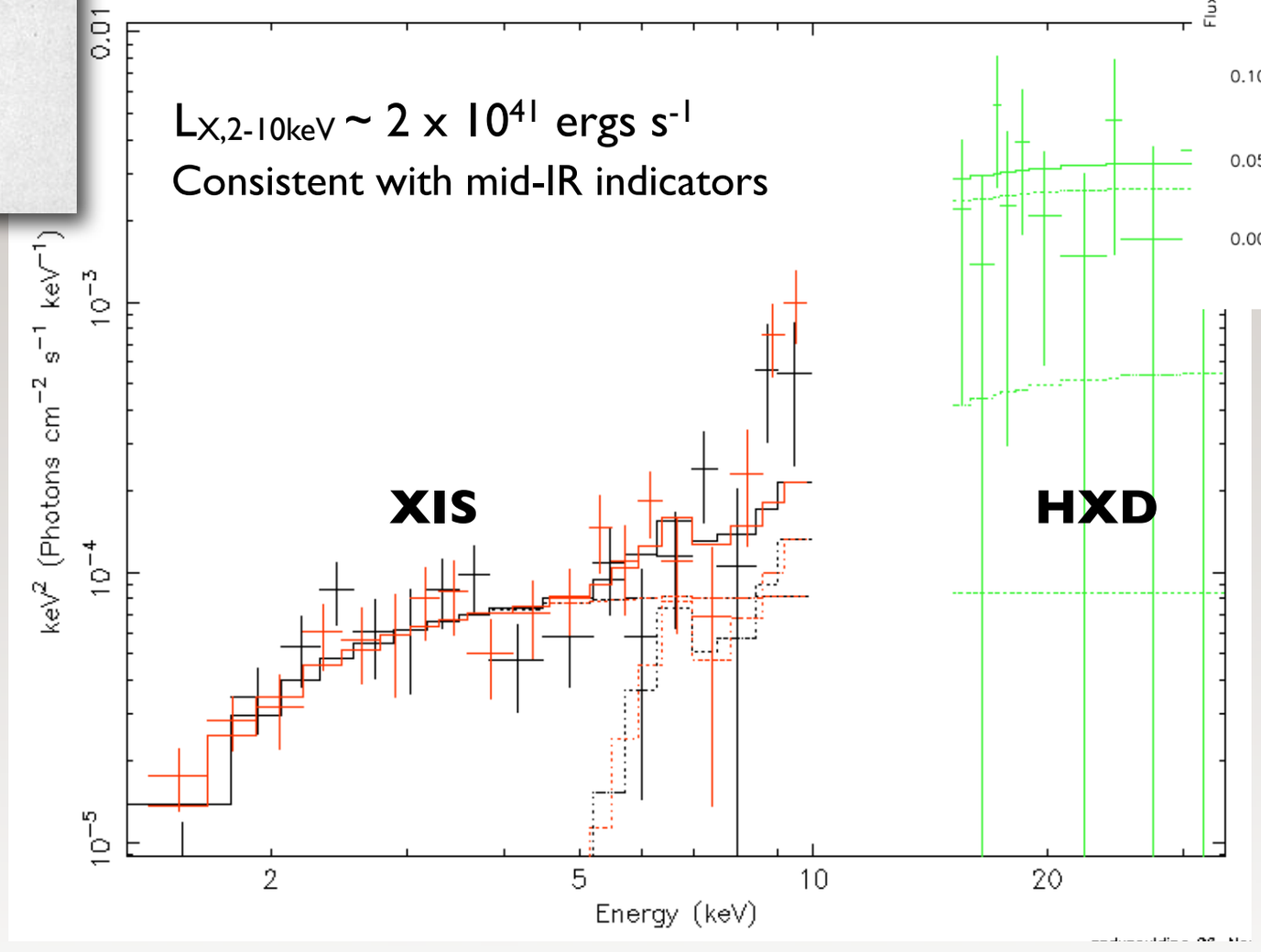


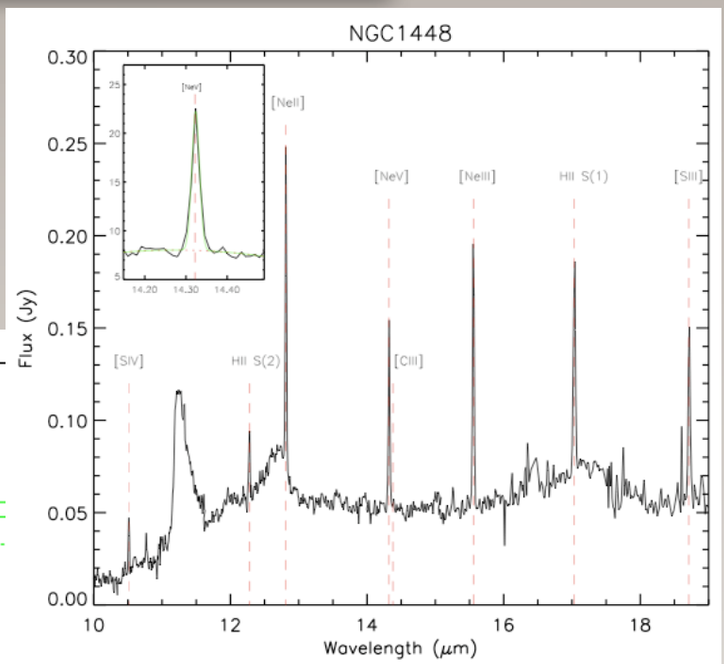
Intrinsic Luminosity of the AGNs

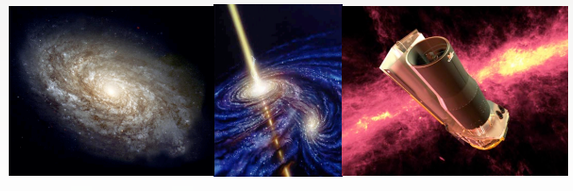
Data and Folded Model for NGC 1448
Suzaku observations

$L_{X,2\text{-}10keV} \sim 2 \times 10^{41}$ ergs s^{-1}

Consistent with mid-IR indicators







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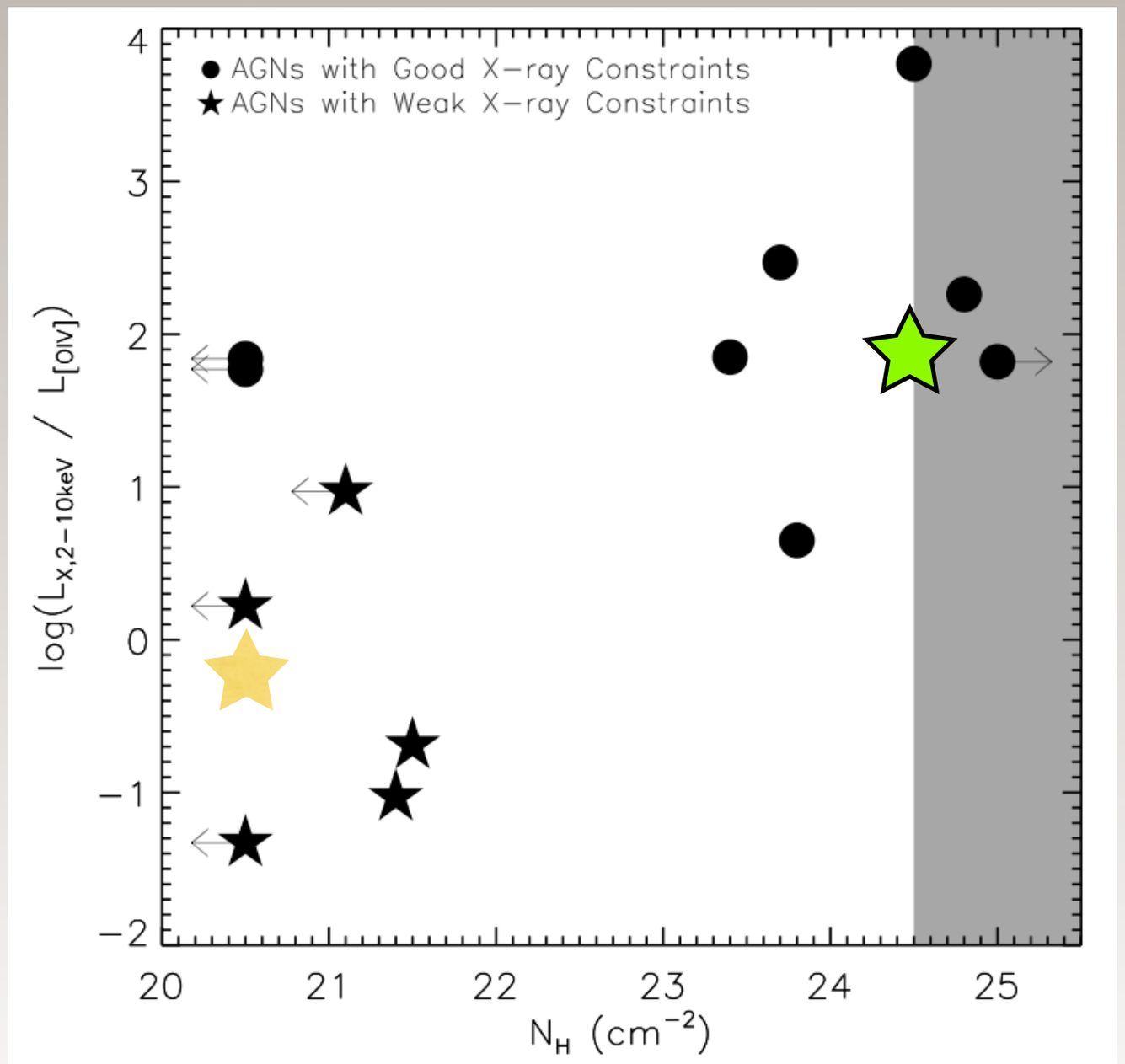

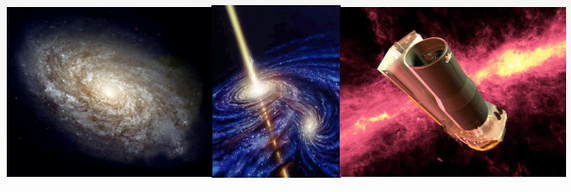

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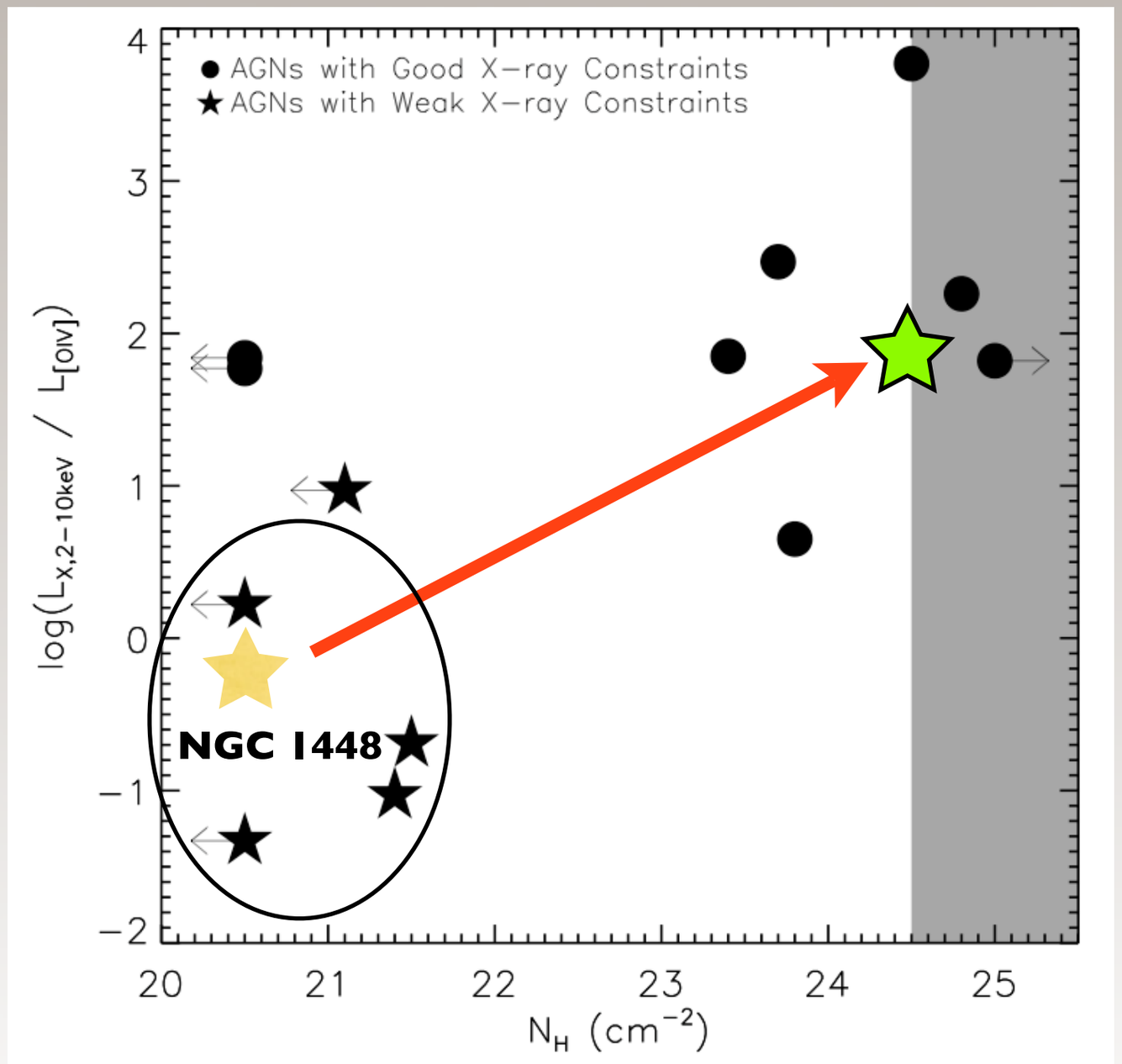
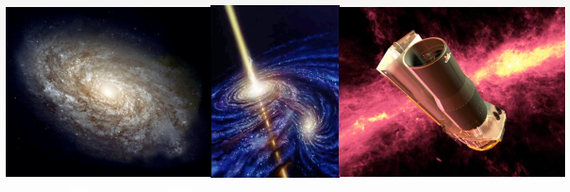
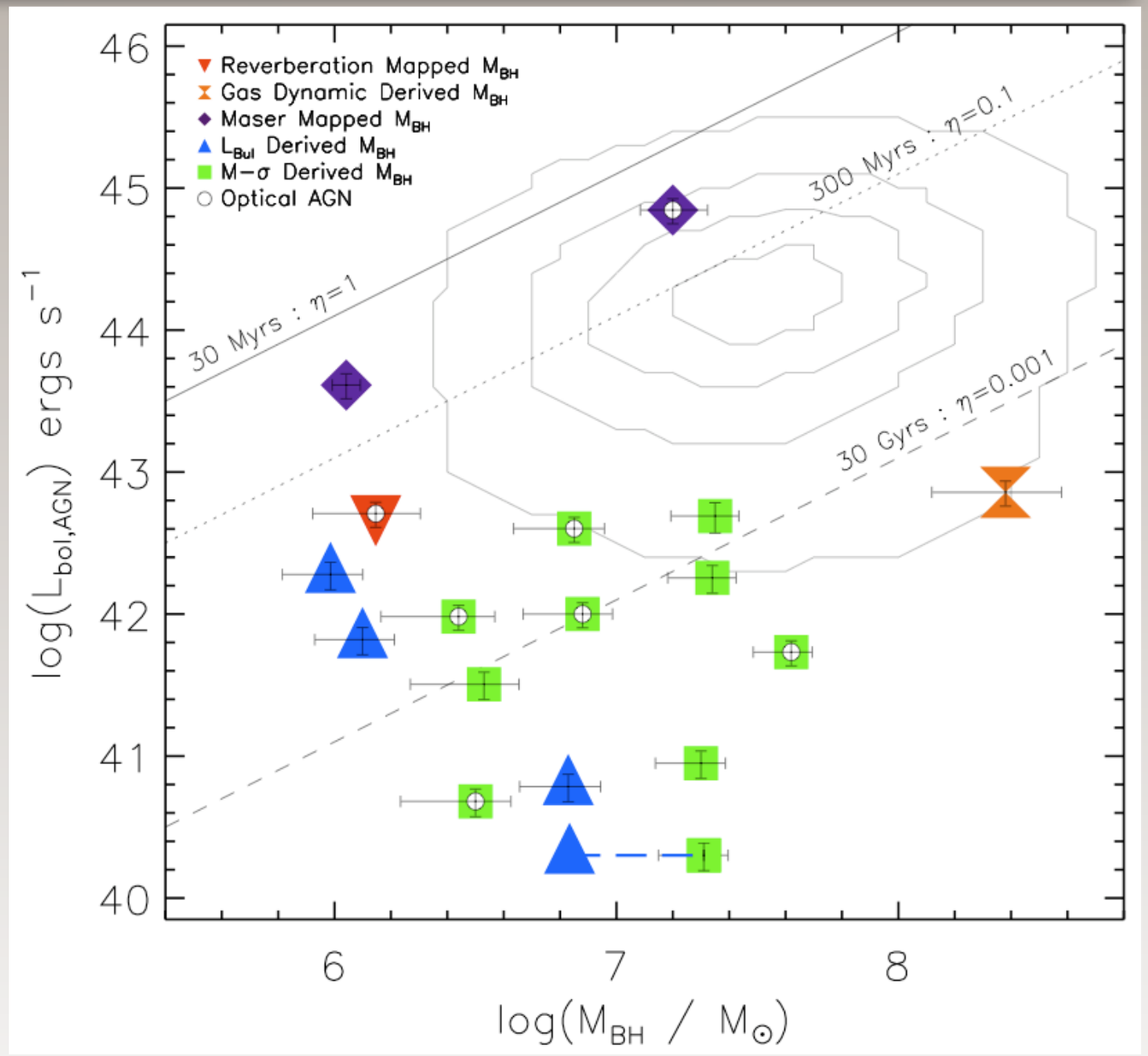




Relative Mass Accretion Rates of local SMBHs

- In general, sample probes lower SMBH mass and lower bolometric luminosities than SDSS
- High Eddington ratio activity occurring in AGNs hosting SMBHs with $M_{BH} \sim 10^6\ M_\odot$
- 3 / 4 of these AGNs not identified in sensitive optical surveys



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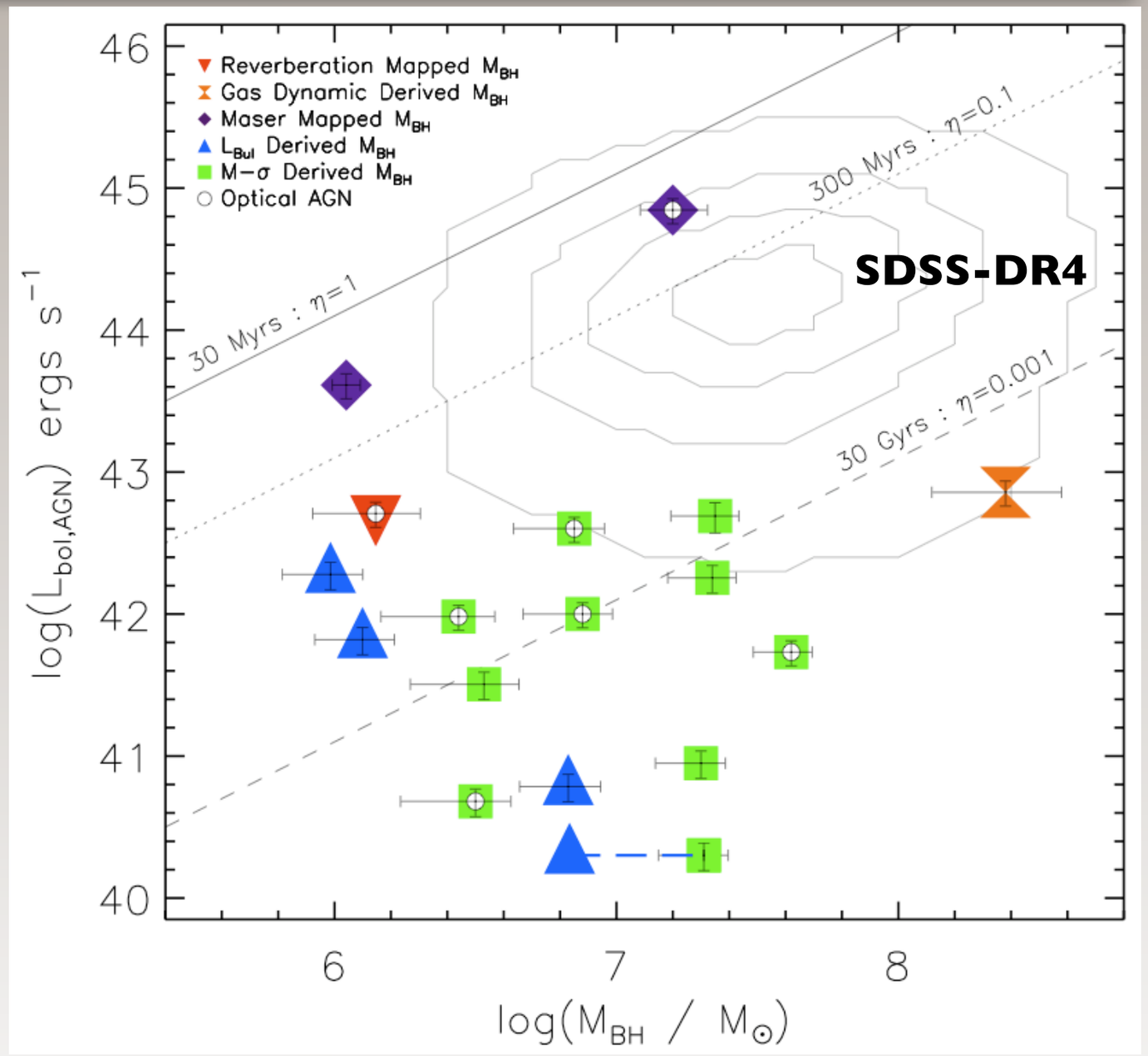

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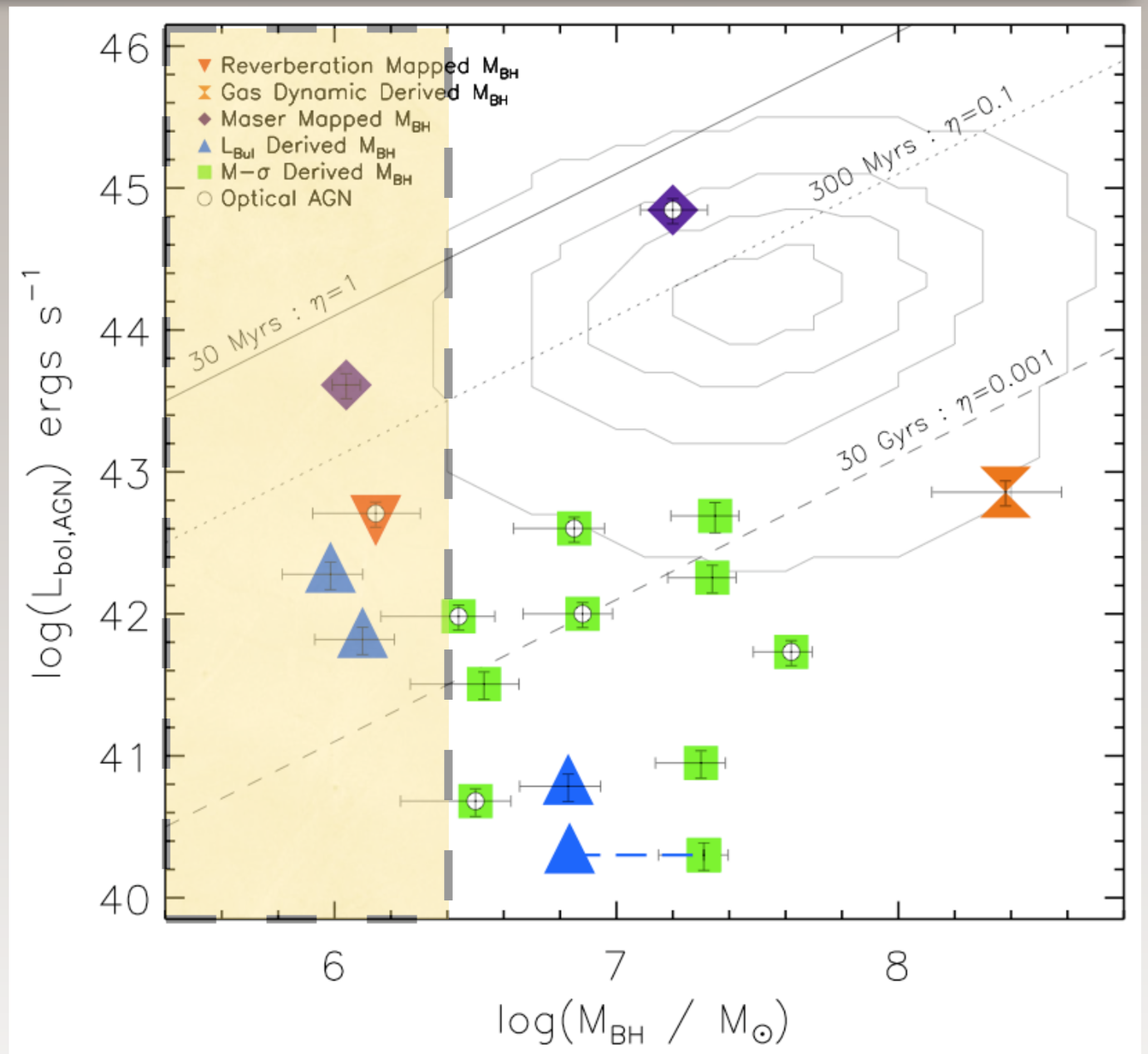
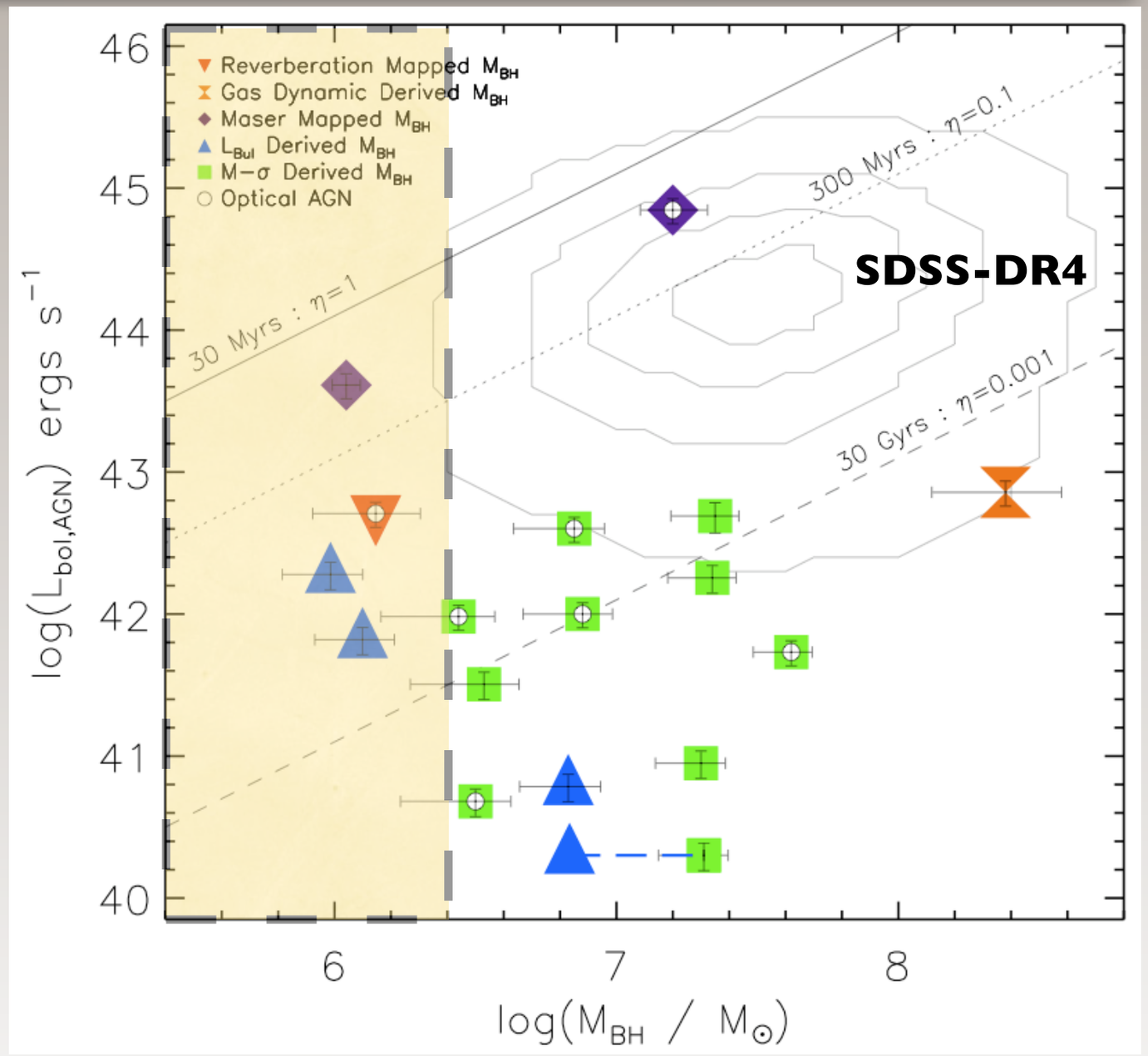


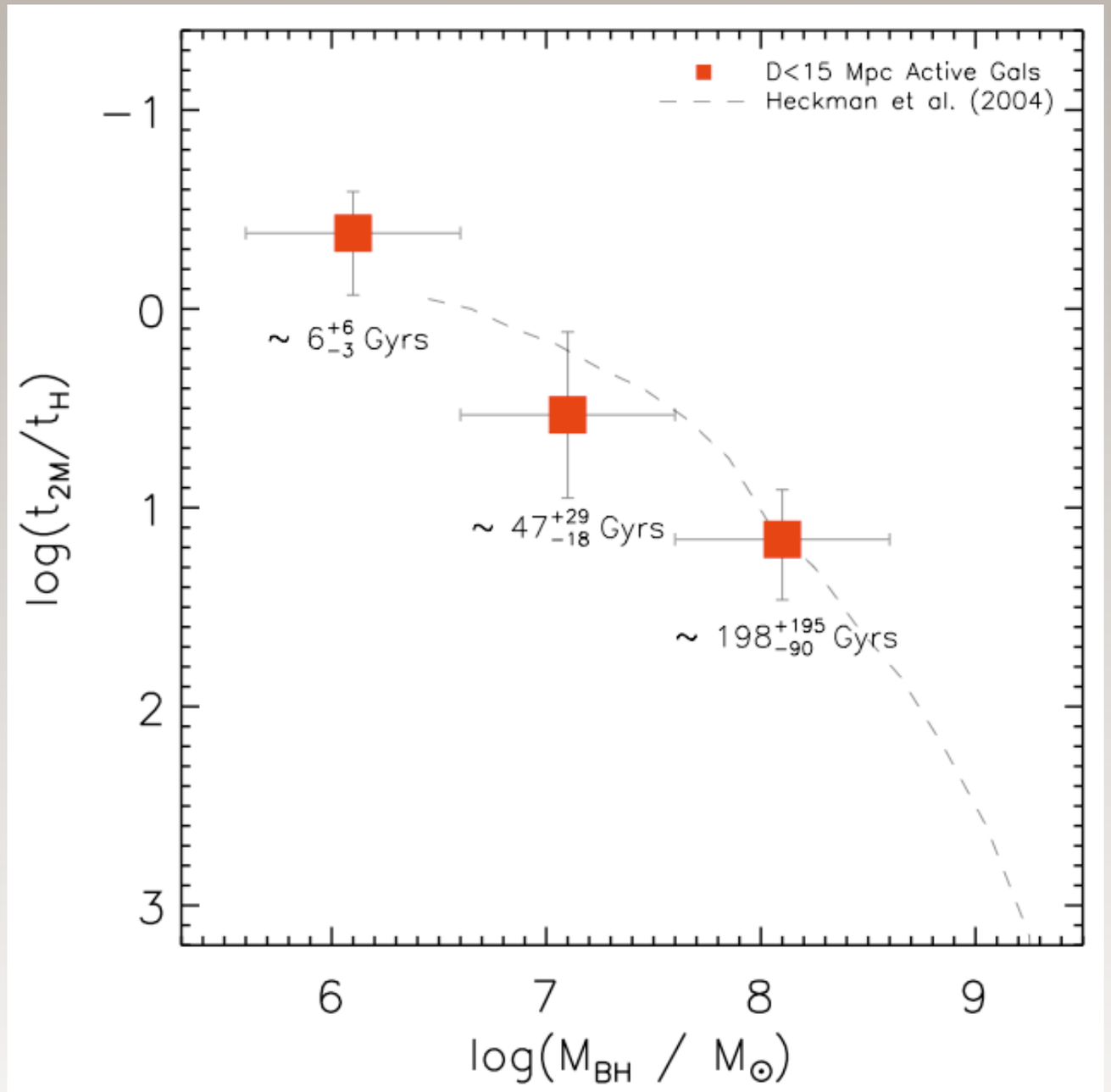
Relative Mass Accretion Rates of local SMBHs

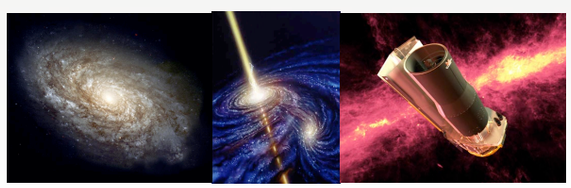
- In general, sample probes lower SMBH mass and lower bolometric luminosities than SDSS
- High Eddington ratio activity occurring in AGNs hosting SMBHs with $M_{BH} \sim 10^6\ M_\odot$
- 3 / 4 of these AGNs not identified in sensitive optical surveys



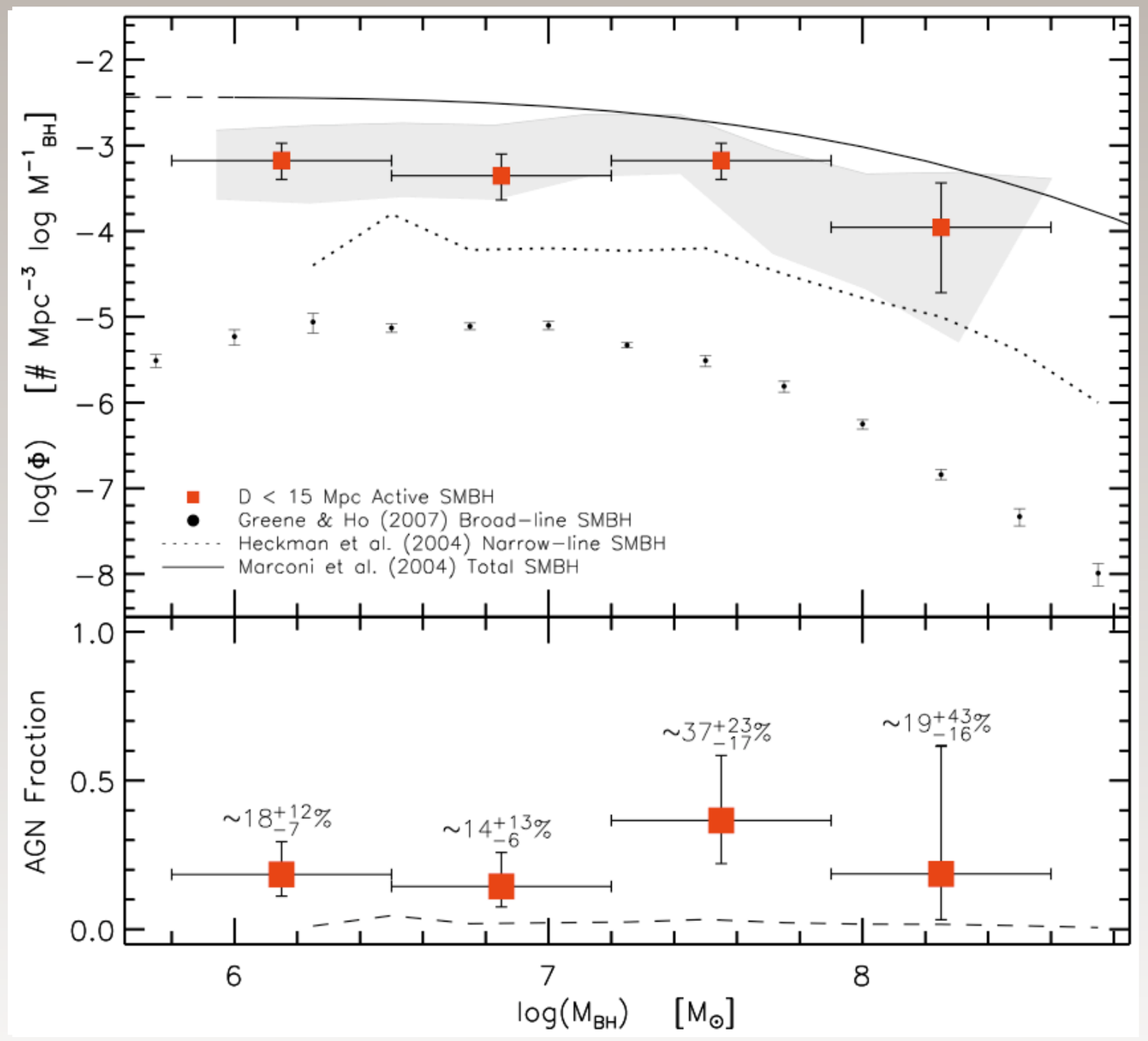
Implied Growth Times of local SMBHs

- Assume moderate spin, a~0.67 i.e., accretion efficiency of ~0.1
- Sample consistent with Heckman et al. (2004) for $M_{BH} > 10^7\ M_\odot$
- Extend to lower SMBHs mass the growth time function of local SMBHs:
  - SMBHs with $M_{BH} \sim 10^6\ M_\odot$ amongst the most rapidly growing in local Universe with mass doubling times consistent with a Hubble time

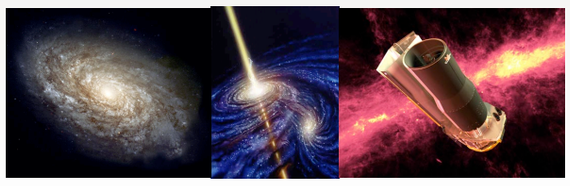




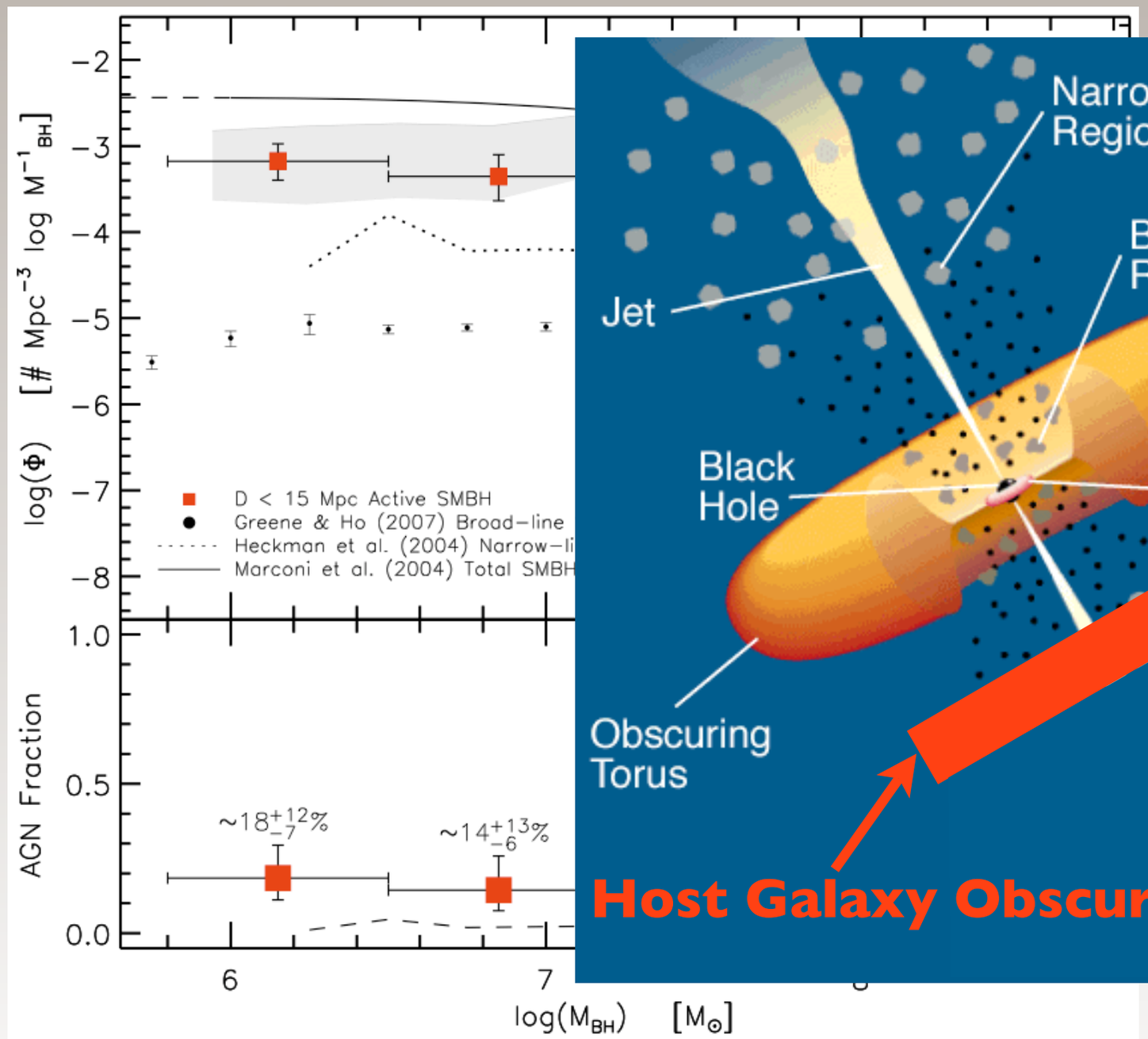
The Space Density of local SMBHs



- Active SMBH density a factor ~10x greater than previously found in large-scale optical surveys
- Relatively small sample (17 AGNs), is this just cosmic variance?
  - Volume does not appear over-dense when compared to Marconi et al. (2004)
  - Monte-Carlo simulation suggests result is robust
- Sample may not be entirely composed of NL-AGNs?..the need for more data



The Space Density of local SMBHs



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Conclusions

- Volume-limited search for AGN activity in the most bolometrically luminous galaxies to D<15 Mpc
- Intrinsically luminous AGNs without good hard X-ray constraints (E>10keV) may be mis-identified even in the local Universe!
- Significant Eddington ratio activity occurring in AGNs hosting SMBHs with $M_{BH} \sim 10^6 M_{\odot}$ with growth-times consistent with the age of the Universe
- Volume density of active SMBHs may be 2x greater than found in large-scale optical surveys
- **Multi-wavelength data is essential to truly constrain the number count and properties of AGNs in the Universe**